TECHNOLOGY DEPT.

Corrosion

IN THIS ISSUE:

FOCUS ON CATHODIC PROTECTION

Combined Cathodic Protection Cleaning of Heat Exchangers . . . 9

Pipeline Cathodic Protection Economics . 12

Cathodic Protection of Miami Seaquarium 16

Automatic Control of a Cathodic Protection System 20

Brass Tube Ends and Plates Under Cathodic Protection 80

Methods and Experiences in Underground Cathodic Protection . . 117

Cathodic Protection Design Based on Ground Potential Distribution . . 122

ADVANCE PROGRAM NACE CONFERENCE
Buffalo, N.Y. March 13-17
Starts on Page 45
Titles and abstracts of 80 technical papers, technical committee meeting schedule

Accelerated Tests for Fiber Reinforced Resin Equipment 73

Effect of Curing Agents on Chemical Stability of Epoxy Resins . . 83

Corrosion Studies of Aluminum in Chemical Process Operations 97

Effect of Sodium Exposure on Mechanical Properties of Zirconium . . 103

Corrosion Resistance of Dense, Impermeable Silicon Carbide 107

ALSO: An alphabetical list of Products at the 1961 Corrosion Show, Page 55

Complete Contents on Pages 4 and 5

Biggest News in Protective Coatings Since 1942...

AMERCOAT No. 99

Amercoat No. 99 offers the time tested protection of vinyl coatings plus virtually foolproof application with cost reductions of up to 42%!*

For application with either airless spray or conventional spray equipment, No. 99 is a companion coating to Amercoat No. 33, the *first* practical vinyl maintenance coating. Introduced in 1942, No. 33 is . . . after 18 years . . . still protecting more than 200 million square feet of steel structures in the severest corrosive environments. And now, through exclusive Amercoat technological developments, you can have the proven protection of No. 33 PLUS the cost-cutting advantages of No. 99.

- Highest solids content of non-mastic vinyls
- Applied by airless spray, one cross sprayed coat easily produces a dry film thickness of 6 mils
- Applied with conventional spray equipment, dry film thickness of 5 mils is obtained with just two coats
- Labor savings of more than 50% have been reported, with material costs cut 35%
- Can be applied directly over Dimetcote, giving a two coat system unequalled by any comparable system
- Recommended for use on all types of structural steel, tank exteriors and ships' hulls

You may obtain complete technical data including a cost analysis showing savings you can realize with this coating by writing to Amercoat Corporation, 4809 Firestone Boulevard, South Gate, California.

**Documented user report furnished on request*

Amercoat® CORPORATION

128

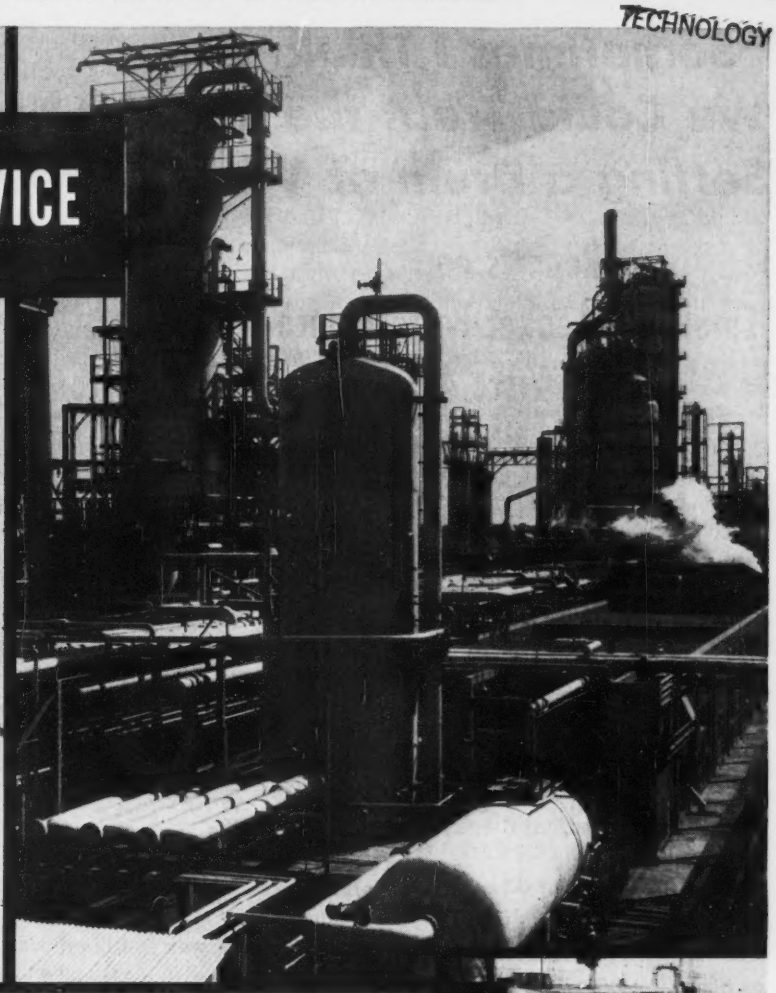
Dept. GM, 4809 Firestone Blvd., South Gate, California

921 Pitner Ave., Evanston, Ill. • 360 Carnegie Ave., Kenilworth, N.J. • 111 Colgate, Buffalo, N.Y. • 2404 Dennis St., Jacksonville, Fla. • 6530 Supply Row, Houston, Tex

TECHNOLOGY DEPT.

another
TRETOLITE SERVICE
report

KONTOL
Corrosion Inhibitor permits low pH operation in refinery's crude unit overhead system



OHIO OIL COMPANY GETS EFFECTIVE CORROSION CONTROL, BETTER PRODUCT QUALITY AT REDUCED COST

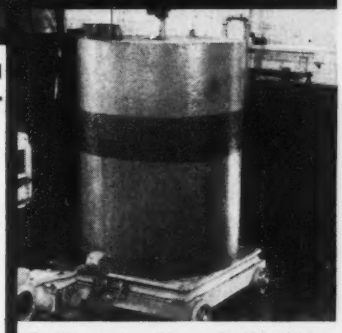
An outstanding performance record compiled over a five-year period in Ohio's refinery at Robinson, Illinois, proves the feasibility of low pH operation augmented by KONTOL* Corrosion Inhibitors.

Prior to inauguration of the low pH-KONTOL program, a high (7.5) pH operation on overhead receiver waters was fouling equipment. Heavy sludge deposits were accumulating ahead of exchanger baffles, and ammonia was contaminating hydrocarbon streams. These troubles limited the refinery to short runs at decreased capacity. *In addition, serious corrosion problems resulted in extensive equipment replacement and repairs after only nine months of operation.*

By changing to a low (4.0-4.5) pH and injecting KONTOL Corrosion Inhibitor at a rate of 10-15 ppm, Ohio has stopped sludging and greatly lowered ammonia contamination. Equipment has been kept clean, reducing maintenance costs and permitting longer runs at increased charge rates. Turnaround inspection has been lengthened to 18-month intervals. *No equipment failures due to corrosion occurred during this five-year period.*

Low pH operation supported by KONTOL corrosion control might offer important advantages for your refining facilities. Ask the Man in the Red Car to explain this program, or write . . .

*Registered trademark, Petrolite Corporation



Facilities such as this one for Kontol injection at various points are part of over-all corrosion control program at Ohio Oil Company's Robinson, Ill., refinery.

PETROLITE
CORPORATION

TRETOLITE COMPANY
DIVISIONS
[illegible] Marshall Avenue, Saint Louis 19, Missouri

SUBSIDIARY AND AFFILIATED COMPANIES
CANADA, Edmonton, Alberta • ENGLAND, London
GERMANY, Frankfurt, a. M. • VENEZUELA, Caracas

REPRESENTATIVES
ARGENTINA, Buenos Aires • BRAZIL, Rio de Janeiro • COLOMBIA, Bogota
ITALY, Rome • JAPAN, Tokyo • KUWAIT, Kuwait • MEXICO, Mexico, D. F.
NETHERLANDS, The Hague • PERU, Talara • TRINIDAD, Port of Spain

KR-60-1

"Sometimes I Think We Could Treat the Oil Just by Setting a Drum of Visco on the Lease"

Reports on Emulsion-Breaker Performance with Visco 485 ... A Typical Visco Formula

Visco 485 is one of dozens of emulsion-breaker formulas that Visco has developed for specific production areas and well conditions. It has taken off like a rocket—often producing dry oil to storage on leases where tank rolling was routine . . . and proving once again that "the tough jobs go to Visco"!

Here are a few instances where Visco 485 has solved difficult treating problems—one of which led to the optimistic statement in the headline.

Rough Gas-Cut Oil and Acid Water

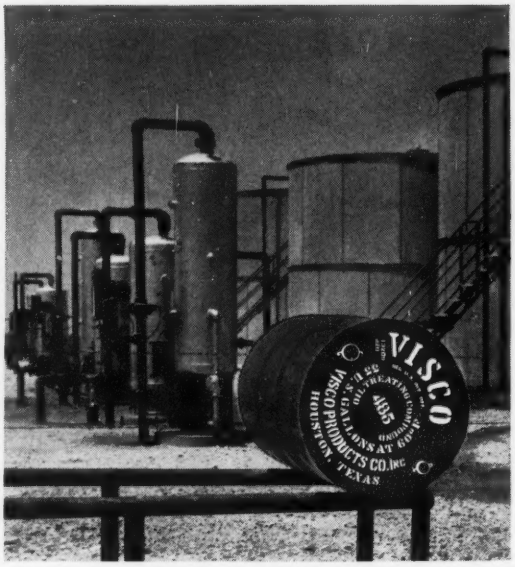
First 200-barrel tank from this new well had had 12 gallons of chemical and as much as 150° of heat . . . 1.0% water was still held up. Five gallons of Visco 485, and 30 minutes' rolling were all it took to sell the tank at 0.2% water.

Cut Chemical Feed 66%

Retreating was common on this lease. 80 to 90 barrels of oil per day took 1½ gallons of chemical. Test of Visco 485 produced 0.1 to 0.2% water in oil with only ½ gallon per day treatment. Results are uniformly good; superintendent plans to put Visco 485 on all remaining leases in the field.

Lowered Gas Heat Bill $300/Month

High tank bottoms, high heat, high treating costs—then Visco 485 and Visco 958 Paraffin Inhibitor were plant tested. Chemical consumption dropped from 10 quarts/500 bbls. to one quart 485 and 2 quarts 958. Tank bottoms disappeared. Heat was lowered from 125°F. to 70°F. for a $300/month gas bill saving. Lowered treating costs with Visco are capped with better oil quality.



Marvel Treater and 485 Cut B.S. & W. 20%

Oil from a new well was 19° gravity, pour point 51°F., 54% asphalt, 21% B.S. & W. Visco 485 was thoroughly dispersed in this heavy crude with a Marvel Treater. Result: 0.4% B.S. & W. Tests without the Marvel Treater could not bring B.S. & W. below 2.3%.

Visco sells or leases Marvel Treaters as an added Visco service to producers. Detailed data will be sent promptly on request.

Try Visco On a Tough One

Pick a well that is giving you emulsion-breaker troubles . . . high treating costs, tight emulsion, tank bottoms or heating problems. Let your Visco Field Service Man make a plant test for you. Odds favor him to come up with answers that can help you cut costs—and get dry oil, too. Call or write for Visco action today.

VISCO PRODUCTS COMPANY
Incorporated
A Unit of Nalco Chemical Company
1020 Holcombe Boulevard **Houston 25, Texas**

Deutsche Nalco-Chemie, G.m.b.H., Frankfort, Germany
Nalco Italiana, S.p.A., Rome, Italy
Nalco de Mexico, S.A. de C.V., Mexico, D.F., Mexico
Nalco de Venezuela, C.A., Caracas, Venezuela

Visco® . . . *Serving the Oil Industry through Practical Applied Science*

Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES
Visco CHEMICALS
Visco SERVICES

This Month in Corrosion Control . . .

HEAT EXCHANGERS and boilers can be protected and cleaned by using cathodic protection at substantial savings over exchangers not so protected. Experience shows results on 20 condensers and on boilers. Turn to Page 9.

CATHODIC PROTECTION economics related to pipelines is thoroughly discussed in an article beginning on Page 12. Case histories are given comparing corrosion costs, cost of metal lost from pipes, estimated cost of cathodic protection and comparisons between bare and coated lines. Some of the data are based on 26 years' experience.

STEEL TANKS housing marine animals at Miami Seaquarium provided a challenging cathodic protection problem to Florida engineers. A report on this interesting application and how some of the unusual problems encountered were solved begins on Page 16.

AUTOMATIC CONTROL of anode output in a cathodic protection system is desirable not only because it reduces the maintenance time required by personnel, but also because it assures steady electrical conditions at the protected surfaces. How this is accomplished with equipment developed by the U.S. Navy is explained beginning on Page 20.

BRASS TUBE PLATES and ends under cathodic protection in condensers using sea water receive more current from zinc alloys anodes than from steel anodes. Results of laboratory tests to establish the relative outputs of the two anode materials are reported beginning on Page 80.

UNDERGROUND CATHODIC PROTECTION of lead sheathed communication cables, bare steel pipe lines and gas transmission and distribution lines are discussed in a 3-part article beginning on Page 117. The article combines the papers given at an NACE North Central Region symposium in Cleveland, Oct. 22, 1959.

GROUND POTENTIAL DISTRIBUTION'S effect on a cathodic protection system designed and results obtained in a system installed in Nagoya are reported beginning on Page 122.

PROGRAM INFORMATION on the NACE 17th Conference at Buffalo in March begins on Page 45. Included are titles and abstracts of 80 technical papers, a schedule of technical committee meetings, information about standing committee meetings and other events. If you are concerned with corrosion control you will want to review this section and pay particular attention to the long list of products to be displayed at the Corrosion Show by 62 exhibitors.

CANADIAN REGION'S Western Division holds its annual meeting at Edmonton February 1-3. Titles of some of the technical papers to be presented are given. Turn to Page 42.

REINFORCED RESIN equipment applications have been hampered in some measure by lack of reliable acceleration tests for the materials used. Beginning on Page 73 is a report on an accelerated test procedure developed at Monsanto.

EPOXY RESINS vary in their durability according to the variations produced by a number of factors, not the least of which is the curing agent used. What effect some curing agents have on these versatile materials is reported in an article beginning on Page 83.

ATOMIC ENERGY considerations are involved in two reports in this issue. One concerns effects of sodium exposure on zirconium and the other tells about reaction of Type 304 stainless steel to thorium dioxide-uranium trioxide slurry. Turn to Pages 93 and 97.

ALUMINUM'S UTILITY in certain chemical process applications is reported beginning on Page 97. Special attention is given to alloys handling 83 percent ammonium nitrate solutions at high temperatures. Another aluminum article beginning on Page 111 gives some data on inhibiting aluminum's corrosion in alkaline solutions.

IMPERMEABLE SILICON CARBIDE's reaction to aqueous solutions of acids, alkalis and salts; in fused salts and molten metals up to 900 C and gases to 1000 C are reported beginning on Page 107.

CONTENTS

Page

This Month in Corrosion Control 3

Little Things Do Count in Corrosion—An Editorial 7

TECHNICAL TOPICS

Page

Techniques and Economics of Combined Cathodic Protection and Cleaning for Heat Exchangers
By M. J. Olive 9

Studies on Determining Pipeline Cathodic Protection Economics
By Frank A. Therrell, Jr. 12

Unusual Problems Encountered in Cathodic Protection of Miami Seaquarium
By Edwin J. Tilton, Jr. 16

Automatic Control of a Platinum Anode Cathodic Protection System
By Roy C. Francis and Leon S. Birnbaum 20

Discussions: Charles Frank Schrieber, Page 22; Raymond F. Vines, Page 22; Thomas P. May, Page 22; Replies by R. C. Francis, Page 22.

RECORD AND REPORT

Page

Dock-Side Plating Job Solves Sub's Galvanic Corrosion Problem...25
Corrosion-Interest Papers to Be Given at Plastics Meeting...25
English Corrosion Group Schedules Godard Paper...25
High Temperature Meeting...25
Abstract Microcards...25
Book News...26
Nickel-Aluminum Alloy Coatings Control Oxidation at 1000 F...28
PIEA and PESA Set Dates for Three Years' Conferences...28
Two Air Pollution Reports...28
Composite Tubing...28
Polyester Exhaust Hood Resists Sulfuric Acid Corrosion...31
Industrial Water Corrosion to Be June Meeting topic...31
Continuous Sheath Cable Extrusion Now Possible...31
Six Dates Are Set for Training School on Spray Equipment...31
Survey of Interest Taken on Soviet, China Abstracts...31
Packaging Course Offered...31
Gas Turbine Conference...31
Feb. 13-16 ASHRAE Meeting...31
New Products...32
Men in the News...36

TECHNICAL COMMITTEE ACTIVITIES

Page

Committee T-1H Sets Up Five Geographic Area Task Groups...37
T-5C-2 Meeting Includes Papers and Study Reports...37
Sixty-Eight Attend T-1C Organization Meeting...37
Inhibitors, Test Specimens Discussed at T-5E Meeting...37
T-6D Expands Its Scope With Four New Task Groups...37
Membership in NACE Technical Unit Committees...37
Task Groups Formed by T-6B to Study Plated Coatings...38
Forty Members and Guests Attend T-2D Tulsa Meeting...38

Index to Advertisers 6

Advertised in This Issue 6

Corrosion Abstracts 57

NACE NEWS

Page

Final Program Given for Houston Section's Feb. 2-3 Short Course...39
South Central Region
Tulsa Section...39
Alamo Section...39
East Texas Section...39
Hanson Elected Chairman for New Orleans Section...39
Shreveport Section Plans 1961 Program Subjects...41
New Teche Section Officers To Be Installed This Month...41
Letters to the Editor...40
Section Calendar...40
National and Regional Meetings and Short Courses...41
Deaths...41
Canadian Region
Titles of Papers and Speakers Given for Western Division Conference...42
Toronto Section...42
Hamilton-Niagara Section...42
Northeast Region
Pittsburgh Section...42
Kanawha Valley Section...42
Baltimore-Washington Section...42
Philadelphia Section...42
Wilmington Section...42
Lehigh Valley Section...42
Southern New England Section...42
North Central Region
Twin City Section...42
Kansas City Section...42
Chicago Section...42
Southwestern Ohio Section...42
Southeast Region
Ohio Valley Section...42
Birmingham Section...42
Western Region
Portland Section Officers Headed by George K. Merz...43
Los Angeles Section...43
San Diego Section...43
San Francisco Area Section...43
Foreign Corrosion Reports...43

ADVANCE PROGRAM

Page

Gamut of Industrial Corrosion Problems Included on Program...45
Only Five Booths Still Available For '61 Corrosion Show...45
Registration Will Begin Sunday, March 12 at 1 p.m...45
General Business Meeting Scheduled for March 15...45
NACE Books Scheduled for Sale at Booth...45
Annual Banquet...45
What NACE Can Do for Management to Be Discussion Topic...46
Program Includes Two Roundtable Discussions...46
Tentative Technical Committee Schedule of Meetings...46
Schedule of Symposia Sessions...47
1961 Corrosion Show Exhibitors...55
Partial List of Products at 1961 Corrosion Show...55

DIRECTORIES

Page

NACE Officers, Directors and Staff... 72
NACE Technical Committees...125

CONTENTS

TECHNICAL SECTION

Page

Accelerated Test Procedure for Evaluation Of Fiber Reinforced Resin Equipment in the Chemical Industry
By Robert A. Cass and Otto H. Fenner 73

Laboratory Investigation of Current Distribution On Brass Tube Plates and Tube Ends of Condensers Using Sea Water
By P. G. Attwood and W. G. Richards 80

Effect of Various Curing Agents on the Chemical Stability Of Epoxy Resins
By Ronald L. DeHoff 83
Discussion: John Delmonte, E. C. Whittier, William C. Hodges, Page 92; Replies by R. L. DeHoff, Page 92

Corrosion-Erosion of Sensitized AISI Type 304 Stainless Steel In a Thorium Dioxide-Uranium Trioxide Slurry
By D. C. Vreeland 93

Corrosion Studies of Aluminum in Chemical Process Operations
By E. H. Cook, Jr., R. L. Horst and W. W. Binger 97
Discussion: Louis J. Zadra, Page 102; Reply by E. H. Cook, Jr., R. L. Horst and W. W. Binger, Page 102

Effect of Sodium Exposure on the Mechanical Properties of Zirconium
By J. C. Bokros 103

Corrosion Resistance of Dense, Impermeable Silicon Carbide
By R. E. Dial and G. E. Mangsen 107
Discussion: H. Howard Bennett, John J. Moran, Page 110; Replies by Roy E. Dial, Page 110

Inhibition of Corrosion of Commercial Aluminum in Alkaline Solutions
By J. Sundararajan and T. L. Rama Char 111

Methods and Experience in Underground Cathodic Protection 117
Part 1—Lead Sheathed Communication Cables, by Oliver Henderson
Part 2—Bare Steel Pipe Lines, by L. H. West
Part 3—Gas Transmission and Distribution Lines, by P. P. Skule

Design for Prevention of Pipe Line Corrosion Based on Survey of Ground Potential Distribution
By Shigeo Fukuta, Shin-ichi Kondo, Nubuo Usami and Shigeki Sekimoto 122

Focus on Cathodic Protection
Pages 9-22, 117 and 122

Copyright 1961 by the National Association of Corrosion Engineers. Reproduction of the contents, either as a whole or in part, is forbidden unless specific permission has been obtained from the Publishers of CORROSION. Articles presented represent the opinions of their authors, and not necessarily those of the Editors of CORROSION, nor the Officers or Members of the National Association of Corrosion Engineers. Manuscripts to be considered for publication should be forwarded, together with illustrations, to the Editor of CORROSION, 1061 M & M Building, Houston 2, Texas.

Corrosion

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U.S.A., as a permanent record of progress in corrosion control.

Vol. 17 January, 1961 No. 1

EDITORIAL STAFF

IVY M. PARKER—Editor

JAMES T. LONGINO
Technical Editor

DALE MILLER
Editorial Assistant

EDITORIAL REVIEW COMMITTEE

FRED M. REINHART, Chairman, National Bureau of Standards, Washington 25, D. C.

Mark F. Adams
A. L. Alexander
Joseph Bigos
W. W. Binger
W. B. Brooks
W. E. Bunting
I. C. Dietze
A. C. Elm
Otto H. Fenner
N. D. Greene
John J. Halbig
B. C. Haworth
T. L. Hoffman
Harry J. Keeling
Frank E. Kulman
Hugh L. Logan
Thomas A. Lowe
D. W. McDowell, Jr.
R. L. McGlasson
Dwight G. Moore
Charles C. Nathan
J. W. Nee
V. B. Pike
A. P. Richards
A. H. Roebuck
J. D. Sudbury
D. H. Thompson
Sidney Tudor
R. M. Wainwright

CORRESPONDENTS

Cecil Phillips, Jr.—Petroleum Refining
K. G. Compton—Telephone, Telegraph and Radio
S. W. Shepard—Non-Metals
Leonard C. Rowe—Transportation Industry
H. E. Stover—Fresh and Salt Water
W. A. Szymanski—Chemical Industry
Gordon B. Smith—Non-Ferrous Metals
Norman D. Groves—Pulp, Paper, Mining and Food
V. M. Kalhauge—Petroleum Production and Pipe Lines
C. P. Larrabee—Ferrous Metals
Herbert W. Dieck—Power
Robert E. Brooks—Light Metals

BUSINESS STAFF

NORMAN E. HAMNER
Managing Editor and Advertising Manager

T. J. HULL
(Executive Secretary NACE) Business Manager

BRAND and BRAND
Western States Advertising Representatives
6314 San Vicente Blvd., Los Angeles 48, Cal.

Address all communications to:
1061 M & M BUILDING
Houston 2, Texas

SUBSCRIPTION RATES (Post Paid)

NON-MEMBERS NACE, CALENDAR YEAR:

U.S. territories & possessions, Canada and Mexico $11
All other addresses $15

SINGLE COPIES, 1959, 60, 61 issues:
Non-members NACE ..... $ 2
NACE members ..... $ 1

Single copies 1957, 58 issues ..... $ 2

Libraries of educational institutions and Public Libraries, U.S., Canada and Mexico only calendar year ..... $ 4

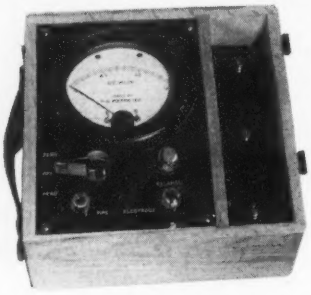
LOST OR DAMAGED COPIES: Claims for replacement without cost must be received within 60 days of date of issue.

Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount in U. S. funds. Second-class Postage Paid at Houston, Texas.

CORROSION Is Indexed Regularly by Engineering Index and Applied Science and Technology Index.

new

PIPE-TO-SOIL VOLTMETER



• INEXPENSIVE
• LIGHTWEIGHT
• EASY-TO-USE

The new Dacca Pipe-to-Soil Voltmeter incorporates features found in far more expensive types — yet it costs less than half. It accurately measures pipe-to-soil, structure-to-structure and anode-to-pipe potentials under any resistance conditions. Simple and fast, it uses only one balancing knob and is easily held in one hand. Extremely easy to understand, it is durable, reliable and compact and uses standard flashlight batteries.

For further information on this, or on the many other AGRA products designed to insure better cathodic protection through improved testing techniques contact your distributor, or write:

AGRA ENGINEERING COMPANY

1537 EAST 10th STREET, TULSA, OKLA.

ADVERTISED IN THIS ISSUE

A

ANODES
Galvanic 19
Graphite 17
Impressed current inside back cover
Magnesium 19, 22, 26, 56
Plating 56
Zinc 19, 56

B

Backfill, coke breeze..... 43
Bushings, dielectric 59

C

CATHODIC PROTECTION
Anodes .....17, 19, 22, 26, inside back cover
Backfill 43
Bushings, dielectric..... 59
Engineering services..26, 33, 38
Fittings, dielectric 59
Installation services 8, 22, 26, 33, 38
Instruments 6
Rectifiers 11, 17, 22, 26, 61
Surveys 33, 38
Unions, dielectric 14, 15
Weld for connections 44
Cement, acid proof..... 65
Citric acid 23
Cleaning acids 23
COATINGS
Application equipment..... 53
Application services 38
Industrial 27, 32
Inorganic zinc silicate..... 24
Maintenance 51
Marine 24
Mastic 53
Pipeline 29, 53
Surveys 27
Vinyl .....inside front cover
Zinc filled inorganic..... 51

D

Descaling acids 23
DIELECTRIC
Bushings 59
Fittings 59
Unions 14, 15

F

Fittings, dielectric 59

G

Graphite 46

I

INHIBITORS
Oil and gas wells...back cover
Oil well 2
Refinery 1
Waterflood operations.....back cover
INSTRUMENTS
Voltmeter, pipe-to-soil..... 6

P

Pipe, plastic 30
PLASTICS
Dielectric bushings 59
Dielectric unions 14, 15
Resin, fiberglass 36
Pipe 30
Tank linings 34, 35
Tape, polyethylene 63
PROCESS EQUIPMENT
Design services 46
Ducts, hoods, tanks..... 36
Graphite 46
Plastic 30
Tank heating, agitation.... 46
Tank linings, plastic.....34, 35
Pumps, plastic lined.....34, 35

R

Rectifiers 11, 18, 22, 26, 61
Research opportunities 41

S

Salt, sea synthetic 43

T

Tank linings.....34, 35
Tapes 49, 63
Tapes, polyethylene 63
Tapes, application equipment.. 49
Testing services 38
Test specimens 42

U

Unions, dielectric 14, 15

V

Valves and fittings, plastic lined 34, 35

W

Water treatment..... 38

INDEX TO ADVERTISERS

Vol. 17 January, 1961 No. 1

Agra Engineering Company..... 6
Amercoat Corporation.....Inside Front Cover
Arno Adhesive Tapes, Inc..... 63
Burndy Corporation 44
Carboline Company 51
Cathodic Protection Service..... 8
Corrosion Engineering Directory..... 38
Corrosion Rectifying Company..... 26
Corrosion Services, Inc. 22
Corrosion Test Supplies 42
Dowell .....Back Cover
Duriron Company, The....Inside Back Cover
du Verre, Incorporated..... 36
Eicor, A Division of The Scranton Corporation..... 11
Electro Rust-Proofing Corporation..... 33
Epco Sales, Inc. 14, 15
Federated Metals Division American Smelting & Refining Company 56
Good-All Electric Manufacturing Co..... 18
Heil Process Equipment Corporation..... 46
Hercules Powder Company Cellulose Products Department.....34, 35
Humble Oil & Refining Company..... 24
International Nickel Company, Inc. The Marketing Services Dept. 41
Kendall Company, The..... 49
Lake Products Company..... 43
Lester Equipment Manufacturing Co., Inc. 61
May Products, Inc. 59
National Association of Corrosion Engineers .....Faces Page 2, 67, 69, 71
National Carbon Company Division of Union Carbide Corporation.. 17
Pfizer, Chas. & Co., Inc. Chemical Sales Division..... 23
Plastic Applicators, Inc. 29
Polyken Sales Division The Kendall Company..... 49
Positions Wanted and Available..... 43
Resistoflex Corporation 30
Royston Laboratories, Inc. 53
Sauereisen Cements 65
Tretolite Company, Division Petrolite Corporation 1
Tube-Kote, Inc. 27
U. S. Stoneware Company 19
Valdura Division American-Marietta Company 32
Visco Products Co., Inc. 2
Wholesale Coke Company 43

Little Things Do Count in Corrosion

MOST OF US are prone to give so much time and attention to the big and dramatic that we have little or none for the small and commonplace. So, we notice and remember facts about corrosion if they refer to huge or catastrophic events and let the little things pass with cursory attention, if we notice them at all.

This predilection causes us to overlook the consequences of corrosion loss and damage to items bought and used by the hundreds of thousands and millions. The money lost on corroded little things, not to mention wasted time and aggravation, often is much greater than that of any single spectacular loss that fully engages our attention. A few of these little things are:

WRIST WATCH BANDS. These days nearly everyone wears a wrist watch. Hundreds of thousands of the bands are of the expandable type, consisting of a combination of plated metals and steel springs. Human sweat attacks these metals, especially when the galvanic relationships are bad. The economic loss from the corrosion of these bands must be in the hundreds of thousands of dollars annually.

EYEGLASS FRAMES. Metal eyeglass frames, especially those which have flexible segments to fit behind the ears, are especially susceptible to corrosion from sweat. When these flexible segments are plated brass, they corrode rapidly. Even when protected by plastic spaghetti tubing, they soon deteriorate because the tubing cracks, exposing the metal beneath. How many thousands of these frames are replaced every year because of corrosion damage cannot be estimated.

LAWN FURNITURE. Steel lawn furniture can be found in hundreds of thousands of homes. Unless carefully repainted about once a year, this furniture, which usually is exposed to the weather, soon rusts and if left untended long enough, is destroyed. Much steel lawn furniture is discarded because the rust stains clothing. When sold, most of it is colorfully and superficially painted.

CYLINDER LOCKS. The familiar cylinder locks found in much of the hardware installed in domestic dwellings, especially individual homes, seems to have been designed by someone who intended to have it destroyed by corrosion. A typical lock is composed of diecast zinc, brass springs, with steel here and there to make the galvanic couples bad. These locks, especially when they are installed on outer doors in a humid environment, either corrode so they can't be opened, or they fall into pieces.

DOMESTIC WATER SERVICE LINES. The pipe that runs between a water meter and the piping of a dwelling represents an investment of only a few dollars—especially if it is constructed of the cheapest "black iron" pipe available. Once this pipe is installed in a trench backfilled with a miscellany of broken concrete, brick bats, sawdust and other rubbish, it may be covered with a concrete walk or driveway. In a few years—or months, in some environments—corrosion pits work through the metal and the water spurts up through the soil. Replacement costs, especially when breaking up and replacing concrete walks and drives is involved, may run into the hundreds. A few extra dollars spent to protect this pipe with a wrapping, and a little care in backfilling, would extend its life indefinitely. Also, the brass meter at one end and the brass valve connecting it to the house piping at the other, make an ideal corrosion cell, which funtions well in the moist soil near the valve and meter.

These are only five of many like cases in the experience of everyone. The loss in each case is relatively small, but when this loss is multiplied by the number that occur, the damage becomes consequential.

It is one of the aims of the National Association of Corrosion Engineers to make everyone responsible for the fabrication and installation of metal plant everywhere alert to the possibility of corrosion damage. NACE has done a great deal to generate this awareness among engineers concerned with industry. So far, very little has been accomplished in this direction among those responsible for end-product consumer goods.

(Those who are interested in learning how corrosive human sweat can be will want to read an article beginning on Page 237 in the August, 1954 issue of CORROSION).

One of 180 grounding electrodes installed to depths of 60 ft. under Houston's newest skyscraper, slated to be the tallest structure west of the Mississippi.

only the best for the biggest

Large or small, Cathodic Protection Service provides turnkey installations. Let one of our experienced engineers show you how Cathodic Protection Service can best solve your individual corrosion problems. Call, wire or write the CPS office nearest you.

CPS

cathodic protection service

P. O. Box 66387 Houston 6, Texas JA 6-1981

Cable Address CATPROSERV

CHICAGO 122 S. Michigan Blvd., Rm. 964 WEbster 9-2763

NEW ORLEANS 1627 Felicity JAckson 2-7316

TULSA 4407 S. Peoria RIverside 2-7393

CORPUS CHRISTI 1620 S. Brownlee TUlip 3-7264

ODESSA 5425 Andrews Hwy. EMerson 6-6731

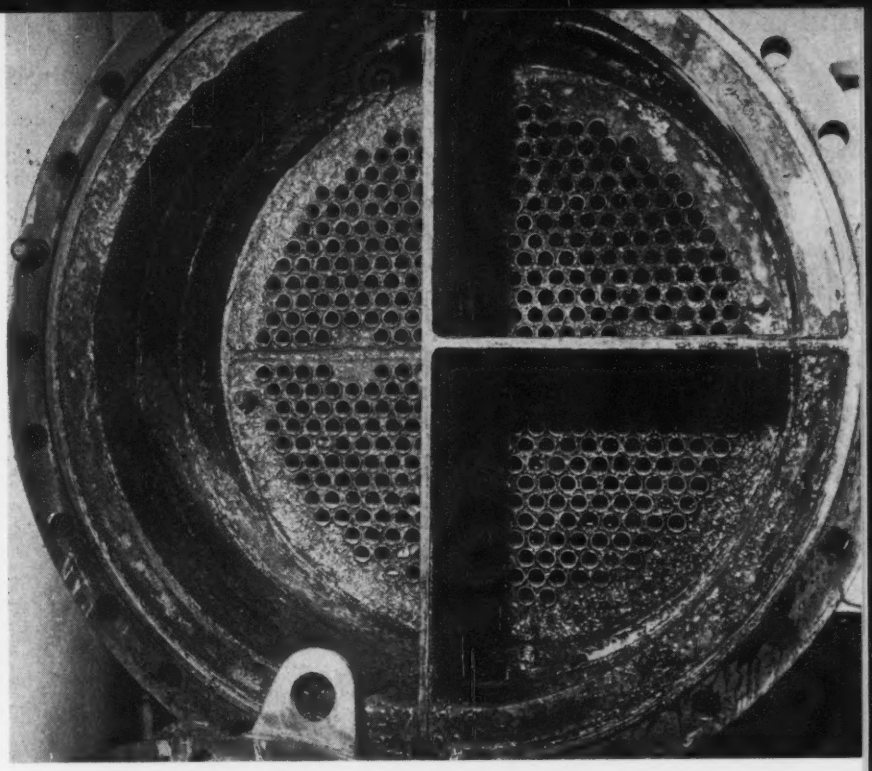


Figure 1--Water box of a heat exchanger after six months with cathodic protection shows little or no deposit or increase in corrosion with calcareous coatings gradually being built up on the steel surfaces.

Abstract

Describes use of cathodic protection and cathodic cleaning of heat exchange equipment. Explains how cathodic protection system was used to supplement water treatment. Data given show 20 condensers were protected by anodes at $800 per year. Cleaning and repair costs for the condensers had been $2000 per year—a saving of $1200 in labor costs alone. Also shows that cathodic cleaning of boilers costs only $60 per boiler. Estimated chemical cleaning cost per boiler was $1500—a saving of $1440 per boiler. 7.4.1

HEAT EXCHANGERS account for a large portion of maintenance expenses at process plants. Considerable time and money are spent in cleaning scale from plugged tubes, repairing leaks or replacing equipment as a result of corrosion damage.

Cathodic protection and cathodic cleaning of heat exchangers as described in this article were used by Arkansas Fuel Oil Corporation to reduce maintenance costs and to improve corrosion protection of plant exchangers by supplementing water treatment with cathodic protection.

Techniques and Economics of

Combined Cathodic Protection And Cleaning for Heat Exchangers*

M. J. Olive

Corrosion Control Associates
Shreveport, Louisiana
Formerly with Arkansas Fuel Oil Corporation

Water Treatment Problems

In most plants, unit operation is dependent on the quantity and quality of cooling water. Care must be taken to provide an adequate and continuous supply. Often water is used which does not have the most desirable properties for cooling. On the coast, salt water may be the only economical choice; in other areas, waters may contain high mineral content or suspended matter which causes corrosion, plugging, deposits and scale. Therefore, the best available water must be mechanically or chemically treated so it can be used economically.

Chemical treatment has been successful in most plants where sufficient and properly applied inhibitors are used. However, in systems where cooling water contains debris, algae, corrosion products and suspended matter or is low in resistivity, deposits or scale build-up often occurs in floating heads and channels. These deposits form galvanic cells which cause heavy local pitting on steel shells and tube sheets.

Also, even if deposits do not occur, crevice corrosion around gaskets and galvanic cells due to bi-metallic couples cause serious metal loss. Chemical treatment is not sufficient to offset this. Inhibitors do not penetrate the heavy build-up but coats the outer surface of the scale particle. This scale not only hampers chemical treatment but also invites sulphate reducing bacteria. Along with excess metal loss, tubes are plugged by the deposits causing poor fluid flow and heat transfer, as shown in Figure 2.

Inspection is one of the best ways to determine whether corrosion is occurring and if protection is needed and economically feasible. Arkansas Fuel Oil Corporation has a company policy of inspecting tube and shell exchangers at regular intervals.

During one of these inspections, excessive corrosion was noted on shells and steel tube sheets. Plugging of tube sheets was causing poor water flow in most exchangers using water on the inside of the tubes and product on the outside. Records showed that most exchangers were dismantled and cleaned every three to six months.

Additional study and inspections showed that water treatment was sufficient except at points of low velocity and deposit accumulation. These inspections showed that the inhibitors were coating the deposits or scale build-up rather than penetrating to the metal. (See Figure 3.) When the scale was

(Continued on Page 10)

★ Revisions of a paper titled "Cathodic Protection of Heat Exchange Equipment" presented at the Western Division Conference, Canadian Region, National Association of Corrosion Engineers, February, 1959, Calgary, Alberta, Canada.

TECHNICAL TOPICS

FOCUS ON CATHODIC PROTECTION

Pages 9-22, 117 and 122

Heat Exchangers—

(Continued From Page 9)

removed, heavy metal loss and deep pitting were found on the tube sheets and heads. Analysis of the scale revealed that it contained 34.5 percent (by weight) iron and 52 percent calcium with traces of silicates.

Because the plant's water treatment was performing properly in the tubes and additional protection was needed only in the channels and floating heads, cathodic protection was chosen as the most logical solution. Water resistivity was measured and analyses made at various points to determine conditions existing inside the exchangers. Resistivity was below 500 ohms per cubic centimeter. The water (6.2 pH) contained large amounts of debris and considerable amounts sulphates and chlorides.

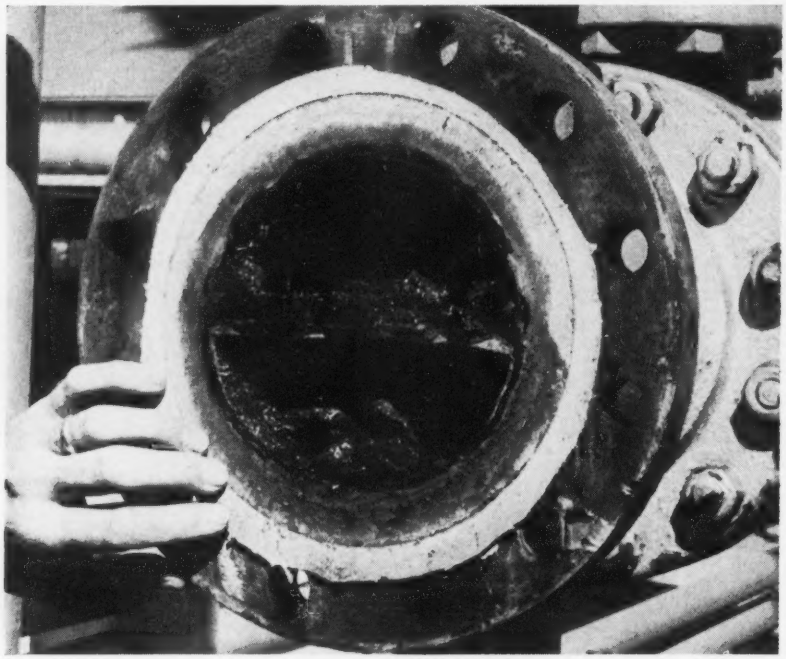


Figure 2—Scale and corrosion product build-up on the water-side of heat exchangers causes plugging and excessive metal loss as shown in this East Texas gasoline plant.

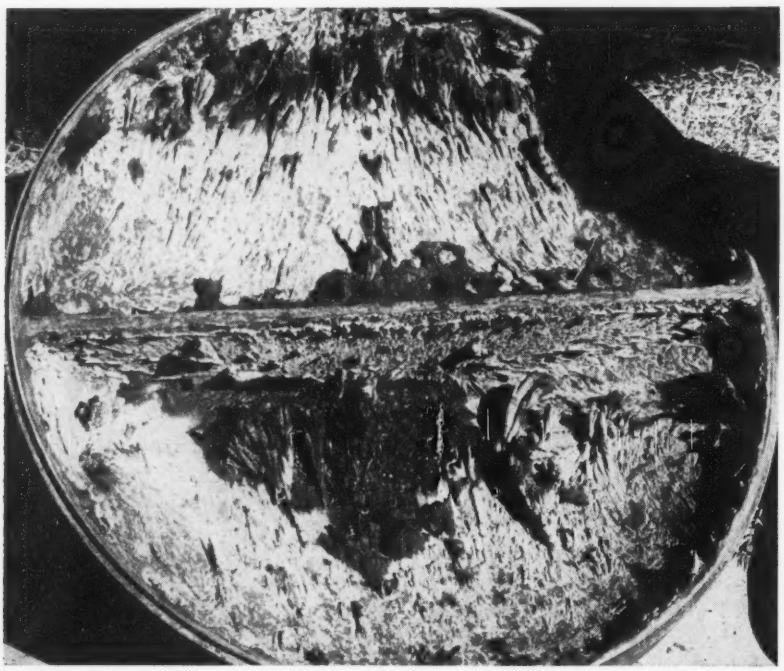


Figure 3—A floating head from a debutanizer condenser shows the heavy deposits after three months' operation. Water treatment apparently was coating the deposit and was not penetrating to the steel surface.

The first installation was to be a test to determine how effective cathodic protection would be and to gather data for future installations. Because exchangers varying from a few inches to four feet in diameter were scattered throughout the plant, use of impressed currents would require complex wiring and insulation. Therefore, sacrificial anodes were chosen to supply the protective current. Uncoated magnesium anodes were installed in the water box and floating head of one of two parallel condensers having identical conditions. Each had water inside the tubes and product on the outside and were having to be cleaned every three months for proper water flow. Each was cleaned before return to service.

After six weeks, both condensers were inspected. The one with anodes showed no deposit or additional metal loss; the other contained heavy corrosion product build-up and active corrosion as before. Because the anode was consumed too rapidly, current regulation was necessary to obtain the desired anode life of one year.

Zinc, having a lower driving potential, would require less regulation than magnesium. But zinc was not used because it becomes cathodic at temperatures above 60 C.

After various current regulation methods were tested, controlled current regulation was obtained by coating the magnesium anodes with polyvinyl chloride and by sizing the exposed area. (See Figure 4.) Data was collected at test condensers to determine how much current per square foot was needed to prevent corrosion and deposits. Tests showed that ten milliamperes per square foot were needed in most plants. Current output of 35 to 50 milliamperes per square inch of magnesium exposed was obtained from the coated anodes. All tests indicated that anodes could protect steel if current over ten milliamperes per square foot was maintained.

Based on this data, coated anodes were installed in each pass of every condenser in two major plants. After one year of operation, each condenser was inspected during its annual turn around. The protected areas had no additional corrosion or scale, and anodes were performing properly. After three years, both plants have installed anodes to last two years with no cleaning or inspections required during the two-year period.

Plant records showed that in one plant 20 condensers were costing the company $2000 per year in labor for cleaning and repairing. Cost of installing anodes in these condensers was $800 per year for a net saving of $1200 in labor alone. The convenience of continuous operation exceeded the anode expense.

Small extruded anodes have been installed in compressor engine oil coolers and water systems with excellent results. Heads and jackets are drilled and tapped with threaded plugs for each installing magnesium rods.

Use of Cathodic Cleaning

Cathodic cleaning of boilers was used in an East Texas plant where silica scale formation was experienced on the water side of direct fired boiler tubes. Inspections showed that one boiler would have to be replaced and the others cleaned. Because chemical cleaning cost per

boiler was estimated at $1500, cathodic cleaning was used.

For this East Texas cleaning job, thin flexible aluminum sheets covered with canvas were connected to a rectifier to serve as anodes. Boilers were filled with water and sodium carbonate added so that the water had a resistivity below 100 ohms per cubic centimeter. About 100 amperes were applied to the tubes through the aluminum anodes.

After 24 hours of cathodic cleaning, the scale had become loose enough for easy removal by a high pressure hose. The tubes were then checked for metal thickness. No replacements were required.

Cost of this cleaning was only $60 per boiler—a saving of $1440 per boiler over the estimated chemical cleaning cost.

Because of the effectiveness and economics of this cleaning process, permanent anodes are being installed so that cathodic protection is achieved and cathodic cleaning can be used when needed.

For other articles of interest on cathodic protection subjects, see pages listed below:

- **Page 40: Letter to Editor, giving photographs and information on 1913 trucks equipped for potential surveys in Chicago and other northeastern cities.**
- **Page 117: Methods and Experience in Underground Cathodic Protection: Part 1—Lead Sheathed Communication Cables, by Oliver Henderson; Part 2—Bare Steel Pipe Lines, by L. H. West; Part 3—Gas Transmission and Distribution Lines, by P. P. Skule.**
- **Page 122: Design for Prevention of Pipe Line Corrosion Based on Survey of Ground Potential Distribution, by Shigeo Fukuta, Shin-ichi Kondo, Nubuo Usami and Shigeki Sekimoto.**

Summary

In waters containing small amounts of hardness and low mineral content, the usefulness of cathodic protection would be questionable. Amount of hardness in water is in proportion to the amount of current density required for protection.

Cathodic protection anodes installed in floating heads and channels will protect only the surfaces exposed to the anode. Cathodic protection current will not protect inside tubes more than one and one-half diameters, because the limited amount of current flowing through the hole will be used on the inside wall of the tube. However, erosion corrosion is minimized because there will be no scale to restrict flow.

Magnesium anodes coated with materials such as polyvinyl chloride will give more economical service in small condensers than impressed current.

In waters of low resistance, current regulation of anodes can be obtained easily by coatings.

Cathodic cleaning of boilers and large condensers is more economical than chemical cleaning. Impressed current for large installation cleaning jobs is more economical than the use of anodes.

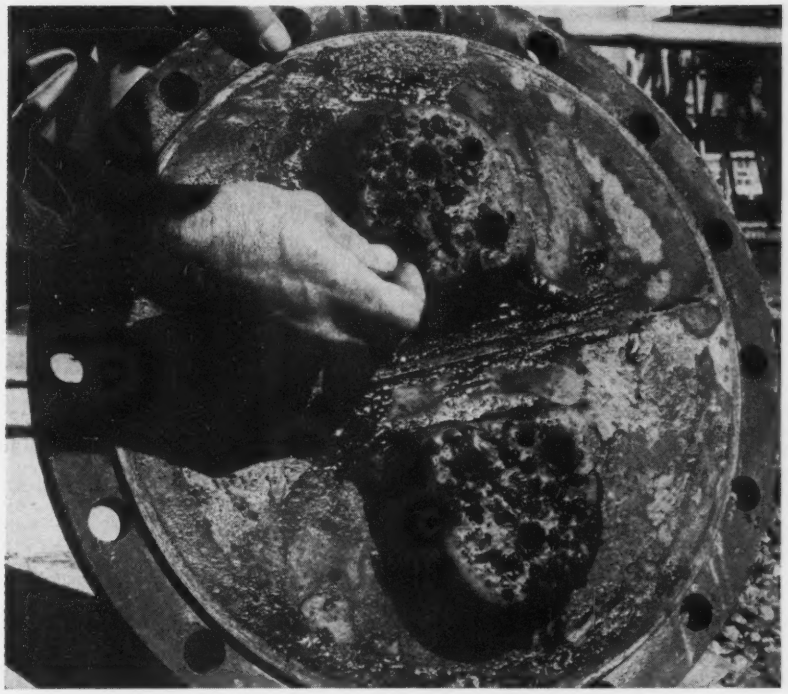
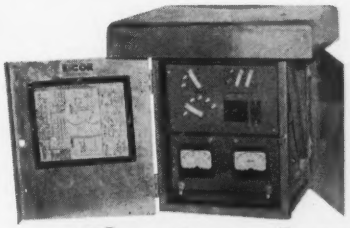


Figure 4—Original anodes installed in water boxes and floating heads of condensers were coated with neoprene for current regulation. The coating blistered and gave poor current regulation. Polyvinyl chloride was later used successfully without blisters forming.



EICOR

The Completely Engineered Cathodic Protection Rectifier

- EICOR'S "complete unit" manufacturing facilities insure: QUALITY CONTROL... ECONOMICAL DESIGN ...PROMPT DELIVERY.
- Field tested EICOR RECTIFIERS are available up to 5,000 watts. Convection air cooled or oil immersed. Single or three phase full wave.
- Standard or special input voltages. All cases are 11 gauge steel (SMALL ARMS PROOF.)
- Case is designed for minimum maintenance in the field and easy accessibility to all components.
- A new approach in cathodic protection rectifier design and manufacture.
- Manufactured in our own plant, under one roof, to the most exacting specifications and rigid controls.
- Write or phone today your nearest representative for descriptive literature and "The Eicor Story."

EICOR Manufacturers of Electrical Equipment for over 25 years.

Chicago 39, Illinois
4059 West North Ave.
Phone HUmbolt 6-2060

Houston (24) Texas
P.O. Box 19333
Phone JA 2-6643
HO 8-7154

Dallas (9) Texas
4807 Elsby Ave.
FLeetwood 2-6085

FACTORY:
517 West Walnut Street
Oglesby, Illinois

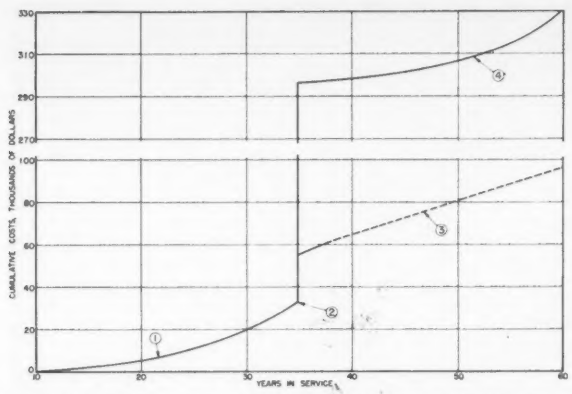


Figure 1—Cumulative cost of leaks (Curve 1) and estimated reconditioning cost (Curve 4) versus cathodic protection cost (Curve 3) on 54 miles of bare 8-inch and 7 miles of bare 10-inch pipeline in service since 1920. Cathodic protection was applied in 1956, as shown by Curve 2.

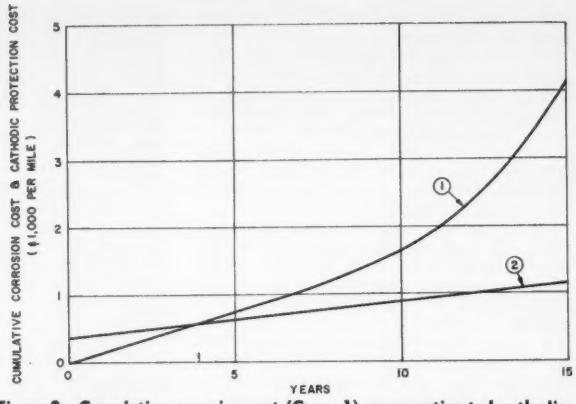


Figure 2—Cumulative corrosion cost (Curve 1) versus estimated cathodic protection cost (Curve 2) per mile on 8-inch bare pipe. Figures are based on 10-year experience on 14.75 miles of pipe.

Studies on Determining

Pipeline Cathodic Protection Economics*

Frank A. Therrell, Jr.
Interstate Oil Pipe Line Company
Shreveport, Louisiana

Abstract

Corrosion cost and cost of corrosion control are estimated from one company's experience. Figures are given on case histories to show corrosion cost, estimated cost of metal loss on pipe, estimated cost of cathodic protection and comparison between costs of protecting bare and coated pipe. Also discusses savings that can be realized through cathodic protection. Compares installation and operation costs of conventional and deep groundbed facilities.
1.2.2

CORROSION COST and cost of corrosion control in pipelines are difficult to determine because of the many variables encountered in underground corrosion. These variables prevent any specific set of figures from being representative of corrosion cost and corrosion control costs for pipelines in general.

The economics of cathodic protection of a pipeline given in this article are based on the experience of Interstate Oil Pipe Line Company and are presented to show one feasible method of calculating the over-all cost of corrosion on pipelines and the corrosion control costs.

Case History of Corrosion Costs

In 1920, two parallel lines of standard weight, bare pipe were laid from Shreveport to Homer, La. About 30 miles of this loop line are still in service, but there have been 109 corrosion leaks.

Because of these many leaks, cathodic protection was applied in 1956. Only four leaks have occurred on this line since the application of cathodic protection, and these leaks occurred soon after the protection was applied.

The estimated cost of these corrosion leaks is shown in Figure 1 with the cost of cathodic protection and the estimated re-conditioning cost on the line. The corrosion cost does not include any amount for the metal loss sustained by the bare pipe during the years it was not protected. No attempt was made to calculate this figure because of the complexities involved and the degree of correctness of such an estimate.

However, consideration of the cost of metal loss led to the investigation on bare pipe exposed in soil without cathodic protection. These figures given below are based on 10 years' experience on a bare line in central Louisiana just southwest of Alexandria.

Laid in 1950, the line was 8-inch, 0.322-inch wall, lapweld, secondhand pipe. About 15 miles were laid bare and about 2 miles were coated with a cold applied coating. No cathodic protection was applied.

The line was taken up in May, 1960, and re-conditioned for further use. Inspection of the coated section after removal of the coating showed no appreciable corrosion except in a few local areas. However, the pipe had an average wall loss of about 25 mils, experienced before 1950. This represented a loss of about 8 percent of original wall thickness.

During re-conditioning operations, inspection of the bare pipe showed uniform corrosion of about 35 to 40 mils of the original wall thickness, representing a 4 percent increase during the 10 years it was in service. There were several areas, however, that had pits 100 mils deep. Because of these severely corroded areas, about 3.4 miles of the pipe were considered unfit for further use.

Besides this metal loss, there were 11 leaks on the line: two in 1956, three in 1958 and six in 1959.

Comparison of corrosion cost and the estimated cost of cathodic protection for this line is given in Figure 2. The corrosion cost per mile shown by Curve 1 rises much faster than the cathodic protection cost (Curve 2) as the length of service is extended. Estimated cost of cathodic protection is shown to indicate the payout of protection over letting the pipe corrode.

Corrosion control costs given here have been developed from the average costs experience on Interstate's pipelines that are cathodically protected. Because of recent development and use of deep groundbeds, the corrosion control costs

★ Revision of a paper titled "Economics of Cathodic Protection" presented at the South Central Region Conference, National Association of Corrosion Engineers, Oct. 25-27, 1960, Tulsa, Okla.

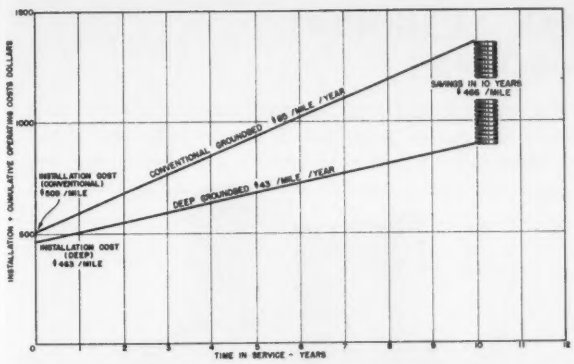

INSTALLATION + CUMULATIVE OPERATING COSTS DOLLARS
TIME IN SERVICE - YEARS
CONVENTIONAL GROUNDBED $95 /MILE /YEAR
DEEP GROUNDBED $43 /MILE /YEAR
SAVINGS IN 10 YEARS $406 /MILE
INSTALLATION COST (CONVENTIONAL) $508 /MILE
INSTALLATION COST (DEEP) $463 /MILE

Figure 3—Conventional versus deep groundbed facilities on bare pipe. Cathodic protection installation cost plus cumulative operating cost per mile on bare 12-inch pipe is shown for conventional and deep groundbed facilities.

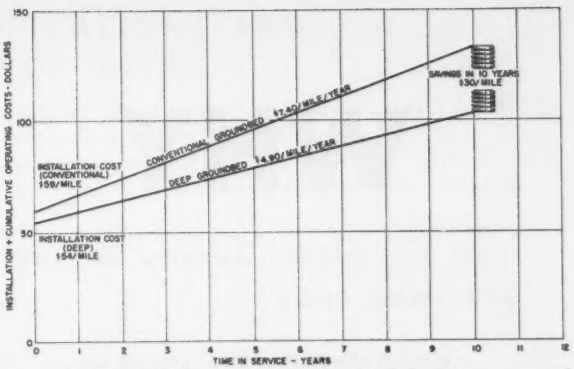

INSTALLATION + CUMULATIVE OPERATING COSTS - DOLLARS
TIME IN SERVICE - YEARS
CONVENTIONAL GROUNDBED $7.40/MILE/YEAR
DEEP GROUNDBED $4.90/MILE/YEAR
SAVINGS IN 10 YEARS $30/MILE
INSTALLATION COST (CONVENTIONAL) $59/MILE
INSTALLATION COST (DEEP) $54/MILE

Figure 4—Conventional versus deep groundbed facilities on coated pipe. Cathodic protection installation cost plus cumulative operating cost per mile on coated 12-inch pipe is shown for conventional and deep groundbed facilities.

are shown in four categories. Figure 3 gives the cathodic protection installation cost and annual operating cost per mile of 12-inch bare pipe by conventional groundbed facilities in comparison with deep groundbed facilities. These figures are representative of lines laid in high resistance soil of about 100,000 ohm-centimeters.

Figure 4 presents a comparison between the cathodic protection installation and annual operating cost per mile of 12-inch coated pipe by conventional groundbed facilities and deep groundbed facilities. These figures are representative of lines laid in soils of 5000 ohm-centimeters or less.

Cathodic Protection Cost Savings

Steps should be taken to eliminate as many of the factors that aggravate corrosion and thus increase the corrosion costs of pipeline service. New structures should be so designed for simple, inexpensive cathodic protection. Basically, this means that lines should be coated and buried wherever possible.

Economics in rectifier-groundbed facilities should be examined closely on each installation. Generally, deep groundbeds can be used more economically for initial installation and operating cost than conventional beds. In areas of high resistance surface soils, the deep groundbed can eliminate considerable expense in preliminary surveys normally conducted to locate conventional groundbeds. More flexibility is achieved in selecting sites where electric power is available. The deep groundbed also can be installed within the existing right-of-way if clearance for another location is difficult to obtain.

In uniform, low resistance soil, the conventional groundbed facility is equal to or slightly lower in installation cost than the deep groundbed. This is particularly true where only small current requirements are needed to provide the desired cathodic protection.

Secondary Economics of Cathodic Protection

With proper design and operation of cathodic protection systems, considerable savings can be realized in pipelines. There is no longer any need to use extra wall thickness in pipeline design to allow corrosion losses. Minimum wall thicknesses can be used to meet line pressure requirements.

Figure 5 shows the approximate total construction cost and cumulative cathodic protection cost on three installations: (1) one mile of 12-inch coated, standard weight pipe, (2) bare, standard weight pipe and (3) coated, thin-wall pipe. The obvious cost savings shown by Curve 3 show the economics of cathodically protecting a coated, thin-wall pipe for long-term service.

Conclusions

The economics of cathodic protection sometimes may seem to be a nebulous matter which is often difficult to sell to management. However, a look at the cost of corrosion on bare pipelines as shown in Figure 2 shows the payout of cathodic protection. With coated lines, there is no question that cathodic protection is indispensable. The lower current requirements of the coated lines reduce installation and operating costs, as shown by a comparison of Figures 3 and 4.

The greatest over-all economy can be realized by applying a good coating to thin-wall pipe, when practical, and cathodically protecting the system by use of deep groundbeds.

Acknowledgment

The author wishes to acknowledge the assistance of Paul Miller, Wilson L. Pevy and Eugene M. Chambers in compiling data for this article.

■

NACE's 17th Annual Conference and 1961 Corrosion Show will be March 13-17 at the Hotel Statler-Hilton in Buffalo, N. Y.

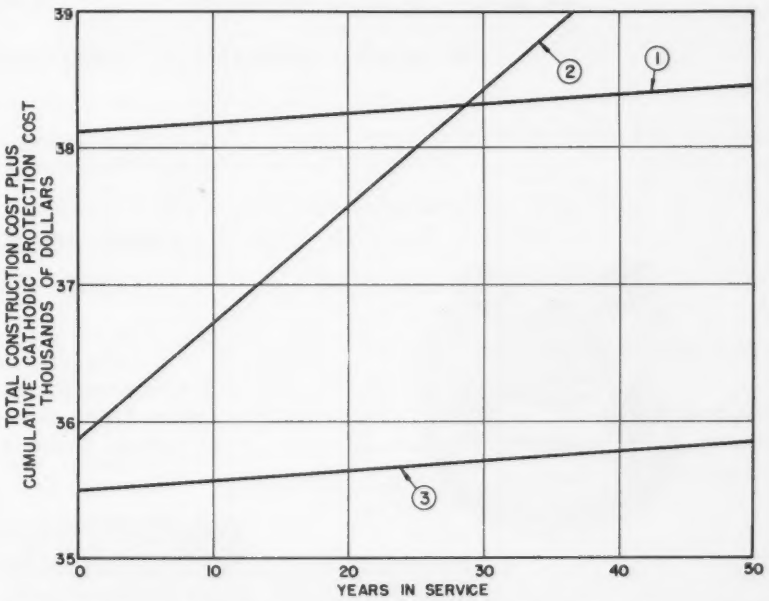


Figure 5—Total costs per mile for pipeline construction plus cumulative cathodic protection cost for 12-inch pipe: Curve 1 is for coated standard weight pipe, Curve 2 is for bare standard weight pipe and Curve 3 is for coated thin-wall pipe.

WHY

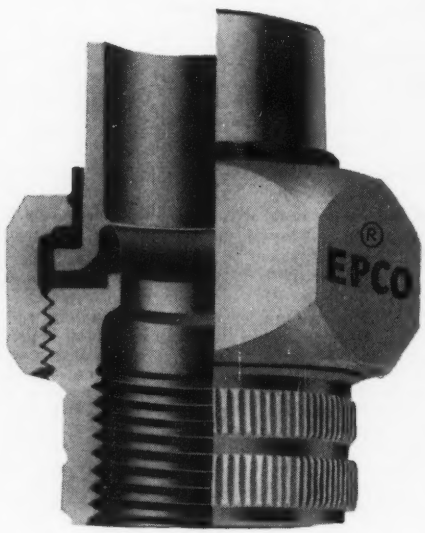
You can safely specify in any plumbing system

EPCO DIELECTRIC UNIONS

To control corrosion caused by galvanic or electrolytic action:

Tests Prove They Will Pass All Federal and Trade Specifications

Over 6,000,000 providing Satisfactory Usage in Domestic, Industrial or Commercial Plumbing Systems.



Designed by engineers to satisfy mechanics

- **SUPERIOR DIELECTRIC STRENGTH**
- **HIGH QUALITY MATERIALS**
- **SKILLED WORKMANSHIP**
- **BALANCED DESIGN**
- **HIGH EFFICIENCY PERFORMANCE**

Over 70 sizes and models to fit your requirements in either Screw or Flange Type Unions. Stock Sizes from ½" to 12"; we solicit your special requirements.

YOUR JOBBER CAN SUPPLY YOUR NEEDS QUICKLY

Write our Dept. S E for latest catalog.

See our Display Booth No. 47 at the Corrosion Show during the NACE Conference in Buffalo March 14-16.

EPCO SALES, INC.

3204 SACKETT AVENUE CLEVELAND 9, OHIO

TECHNICAL SPECIFICATIONS AND PERFORMANCE DATA

The chart below was prepared from tests made by a leading independent laboratory. It discloses the fact that EPCO leads the other makes in balanced design, dielectric performance and standard physical specifications. Other manufacturers with a score of only 71% and under are decisively below respectful specifications. With EPCO'S balanced adherence to specifications, you can meet your plumbing code requirements safely and economically.

Manufacturers of Insulated Pipe Fittings to Control Galvanic Corrsion	Does Fitting Meet Current Value For Proper Control of Galvanic Corrosion Not to Exceed 1% of Short Circuit Current	Does Ultimate Voltage Breakdown Meet Maximum Requirement to Protect Dry Lines Such as Gas or Air	Does Tensile Strength Meet Federal Specification WW-U-531-A	Does Bursting or Leakage Pressure Meet Rated 250 Pounds Per Square Inch at Four to One Safety Factor	Does Construction Meet Standards for Similar Fittings Such as ASA#B16.8 of American Society of Mech. Eng.	Does Zinc Plating Meet Minimum Federal Specification of 0.0005 Ins.	Does Fitting Have Gasket Retainer To Prevent Closing of Aperture of Union After Assembly	Total Score
Manufacture EPCO	YES	8 TIMES OVER	50% OVER	YES	50% OVER	20% OVER	YES	7 OUT OF 7 100%
Manufacture A	YES	8 TIMES OVER	30% OVER	YES	UNDER 40%	UNDER 40%	NO	4 OUT OF 7 57%
Manufacture B	YES	20 TIMES OVER	UNDER 70%	NO	0% OVER	300% OVER	NO	4 OUT OF 7 57%
Manufacture C	YES	8 TIMES OVER	UNDER 50%	YES	5% OVER	UNDER 40%	NO	4 OUT OF 7 57%
Manufacture D	YES	4 TIMES OVER	UNDER 75%	YES	DOES NOT APPLY	UNDER 60%	DOES NOT APPLY	3 OUT OF 5 60%
Manufacture E	YES	7 TIMES OVER	UNDER 30%	YES	UNDER 10%	UNDER 50%	NO	3 OUT OF 7 43%
Manufacture F	YES	6 TIMES OVER	UNDER 45%	YES	8% OVER	300% OVER	NO	5 OUT OF 7 71%
Manufacture G	YES	5 TIMES OVER	UNDER 40%	NO	DOES NOT APPLY	UNDER 60%	DOES NOT APPLY	2 OUT OF 5 40%

Tested by U. S. Testing Co., Inc. Report No. 51432, dated February 13, 1959.

Tests were made on ¾" fittings purchased on the open market of known manufacturers at the time of this test. The flange type union was not included in this test in order to keep results comparable.

DIELECTRIC UNIONS MANUFACTURED BY ECOFF PRODUCTS CO., INC., ARE METAL CONNECTIONS ON BOTH ENDS OF UNION

Manufacturer A — Dielectric unions are metal connections on both ends of union.

Manufacturer B — Dielectric unions are Nylon connection on one end of union and metal connection on other end.

Manufacturer C — Dielectric unions are Nylon connection on one end of union and metal connection on other end.

Manufacturer D — Dielectric coupling is Nylon connection on both ends of coupling.

Manufacturer E — Dielectric unions are metal connections on both ends of union.

Manufacturer F — Dielectric unions are metal connections on both ends of union.

Manufacturer G — Dielectric coupling is Nylon connection on both ends of coupling.

EPCO SALES, INC.

3204 SACKETT AVENUE CLEVELAND 9, OHIO

Unusual Problems Encountered in Cathodic Protection of Miami Seaquarium*

Abstract

Unusual problems are described in designing and installing a cathodic protection system for two steel tanks at the Miami Seaquarium. Problems involved working under water because tanks could not be drained and damage to anodes and their leads by large fish and sea turtles. Vertically hung anodes were not suited because they would interfere with performances of the porpoises. Descriptions of anodes, conduits and volume of impressed current are given. 5.2.1

Edwin J. Tilton, Jr.
Tilton and Associates
Coral Gables, Florida

CORROSION PROBLEMS at the Miami Seaquarium presented several unusual problems for the corrosion engineers who were asked to determine the cause of leaks in the water tanks.

The first problem encountered was that inspection had to be made under water. The tanks could not be drained for inspection because the valuable marine life such as sharks, trained porpoises, sea turtles and moray eels could not be moved to other tanks. About half the marine specimens would be killed in such an operation. Therefore, the engineer had to become a skin diver to inspect the tanks' inside surfaces.

The tanks have ⅜-inch cold rolled steel walls lined with a 2-inch thick cement mortar lining. This cement is sealed at the bottom with a mastic tar coating. Inspection showed an iron oxide film on the cement in several areas. Near the bottom of the wall, the cement was chipped loose from the steel and was very soft in areas next to the steel, probably indicating a heavy concentration of hydrogen gas. It is surmised that excreta from fish and mammals may form hydrogen sulfide in the vicinity of the steel.

Figure 1—Corrosion engineer had to become a skin diver to install anodes in 18-foot deep steel tank at Miami Seaquarium. Anodes had to be anchored to tank floor so that large fish and turtles would not tear them loose.

Examination showed corroded areas on the steel walls eight inches long and two inches wide with complete perforations through the ⅜-inch steel at the centers of the corroded areas. Weight loss on one tank was estimated at 1200 pounds of steel.

A potential test made on the tanks showed a —0.18 volts with reference to a silver-silver chloride half cell immersed in the salt water. For proper protection, steel in moving salt water should have a potential of —0.83 volts with reference to a silver-silver chloride half cell.[1]

The tank's accelerated corrosion probably was caused by the water velocity. Water is re-circulated and reaches a velocity of about two knots near the tank walls. This could increase the corrosion rate by removing the oxidized film, thus exposing new metal to attack.

The pitting and perforations probably were in localized areas because of breaks in mill scale. At these breaks, the base metal is cathodic to the mill scale, thus permitting rapid galvanic attack and deep pitting.

Localized corrosion probably was increased by the addition of copper sulfate to the water to control algae.

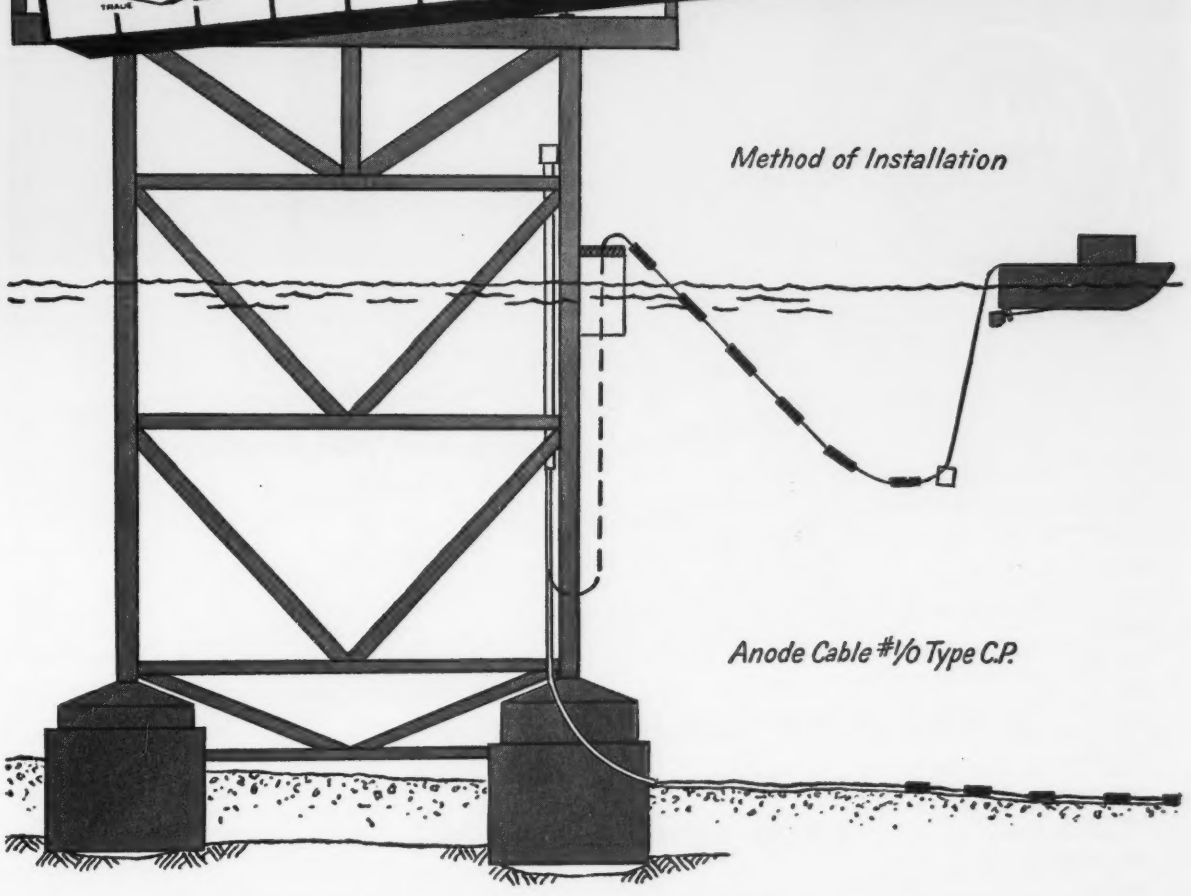
Cathodic Protection Problems

Normally, a corrosion engineer designing a cathodic protection installation need not be concerned with the fact that installation must be done under water or that marine life such as sea turtles will crush conduit lines; that impressed currents may be fatal to valuable fish, that marine life may be harmed by metal dissolved from sacri-

(Continued on Page 18)

★Revision of a paper titled "Problem Involved in the Corrosion Mitigation of the Miami Seaquarium" presented at the Florida General Conference Short Course on Corrosion, sponsored by the Miami and Jacksonville Sections, National Association of Corrosion Engineers, November 7-11, 1960, Miami, Florida.

Anode notes from National Carbon Company



PROTECTION OF A $4,750,000 OFFSHORE DRILLING RIG

Corrosion engineers of a large oil company decided to use impressed current cathodic protection on the underwater foundation of an offshore drilling rig.

Six strings of 10 "National" NA Graphite Type QA Anodes* were used to provide a distributed anode bed. They were assembled on 1/0 C.P. cable at fifteen foot spacings. Anode strings were placed radially around the platform on the sea bottom with the first anode approximately 200 feet from the platform base. The anode strings are held in place by 12"x12"x16" concrete anchor blocks at the end of each string.

"National" NA Graphite Anodes were selected because of proved long anode life (about 0.1 lbs./amp. year consumption in free moving salt water) and low initial cost.

*Anodes were sold by The Vanode Company, Pasadena, California

"National", "N" and Shield Device, and "Union Carbide" are registered trade-marks for products of

NATIONAL CARBON COMPANY
Division of Union Carbide Corporation • 270 Park Avenue, New York 17, New York
IN CANADA: Union Carbide Canada Limited, Toronto

UNION CARBIDE

The Complete Line

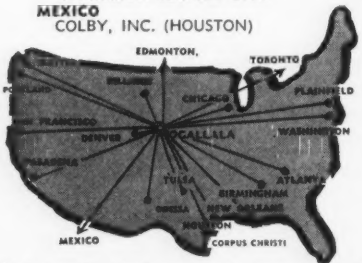
FULLY REPRESENTED IN YOUR AREA

Good-All
CATHODIC PROTECTION RECTIFIERS

ONLY Good-All is backed by the services of a nation-wide group of the finest corrosion control firms. These well known companies are as near as your phone and ready to serve you.

ATLANTA
STEELE AND ASSOCIATES INC.
BILLINGS
WESTERN CORROSION SERVICE
BIRMINGHAM
STEEL AND ASSOCIATES, INC.
CHICAGO
SALES ENGINEERING INC.
CORPUS CHRISTI
CATHODIC PROTECTION SERVICE
DENVER
CORROGARD INC.
HOUSTON
CATHODIC PROTECTION SERVICE
NEW ORLEANS
CATHODIC PROTECTION SERVICE
ODESSA
CATHODIC PROTECTION SERVICE
PASADENA
THE VANODE COMPANY
PLAINFIELD
STUART STEEL PROTECTION CORP.
PORTLAND
JOSEPH F. TARABA CO.
SAN FRANCISCO
THE PIPELINE PROTECTION CO.
SEATTLE
JOSEPH F. TARABA CO.
TULSA
CATHODIC PROTECTION SERVICE
CORROSION SERVICES INC.

EDMONTON, CANADA
CAPROCO
TORONTO, CANADA
CORROSION SERVICE LTD.
MEXICO
COLBY, INC. (HOUSTON)



See the Good-All Representative in your area.

GOOD-ALL ELECTRIC MFG. CO. Ogallala, Nebr.
A SUBSIDIARY OF THOMPSON-RAMO-WOOLDRIDGE INC.

Unusual Problems—

(Continued From Page 16)

ficial anodes or that anodes might get in the way of performing porpoises.

To meet these unusual conditions, 4 by 80-inch carbon anodes were installed with a designed useful life of ten years. Anode leads were sealed in ¾-inch polyvinylchloride pipe. Large sea turtles snapped at and crushed metal conduit used initially. Anode conduits and anodes were anchored to the tank floor and walls with nylon and PVC cable clamps by Monel bolts and plastic expansion lags. Anodes could not be hung vertically in the tank because they would interfere with the performances of the porpoises. Anchoring of anodes and conduits was necessary because the sawfish attempted to tear up anything loose in the tanks. (See Figures 1 and 2.)

Special anodes with water-tight ends shown in Figure 3 were necessary to prevent large fish, turtles and sharks from destroying the conductors.

The two tanks required six anodes each. Each tank had a separate control system with each anode individually controlled. This individual anode control permitted driving current into specific areas of the tank wall as required for proper protection.

Placement of Anodes in Tanks

The six anodes in the 80-foot diameter, 18-foot deep tank were placed horizontally about ten feet from the wall and parallel to the sides. They were about 32 feet apart, center to center. The six anodes in the smaller reef tank (50-foot diameter, 18 feet deep) were placed about 14 feet from tank walls and perpendicular to the sides. They are about 12 feet apart, center to center.

Impressed Current on Anodes

When the installation was completed, the 18-ampere output of the rectifier on the larger tank was adjusted to supply 3 amperes to each of the six anodes. This produced the desired negative potential of —0.83 volt.

Figure 2—Giant 700-pound Jew fish is shown near the PVC conduit in which the anode leads were sealed for protection against the marine life in the steel tank.

The installation is being supervised carefully to make certain that the steel tank does not reach a negative potential over —0.98 volts. If this potential should be reached, the cement lining would lose its bond to the steel, thus aggravating the existing corrosion problem.

Marine life in the tanks is being studied also to make certain that no harmful effects result from the cathodic protection system. This is important because operators of the Seaquarium place a value of about $40 to $60 thousand dollars on a trained porpoise.

A study is being made to determine the feasibility of using ultra-violet rays to kill algae, thus eliminating the need for copper sulfate treatment.

References

1. H. S. Preiser and F. E. Cook. Cathodic Protection of an Active Ship Using a Trailing Platinum-Clad Anode. *Corrosion*, **13**, 125t-131t (1957) February.

Figure 3—Special carbon anodes with water tight protected ends were required to prevent large fish, turtles and sharks from destroying the conductors. PVC clamps also were necessary to anchor the anodes to the tank floor.

Protect PLANT AND EQUIPMENT
WITH VERSATILE TYGON PLASTICS
. . . AND SAVE THREE WAYS
1 LOWER MAINTENANCE COSTS
2 LESS PLANT "DOWN-TIME"
3 LESS SOLUTION LOSS

When you use versatile Tygon Plastics to protect buidings, tanks, ducts, pipe, valves, pumps and other equipment from corrosive attack, you're not only sure of longer, maintenance-free life, but: 1. You reduce "Down-time" resulting from taking equipment out of production for repairs or replacement, and 2. You avoid product or solution loss from corrosive contamination.

Tygon Plastics are resistant to a wider range of chemicals than any other material of construction, with the exception of glass and chemical stoneware. Yet, Tygon Plastics have a versatility in use approached by no other material.

For example: Tygon sheet linings $\frac{1}{32}$" thick can be applied to tanks, ducts, pipe and valves from 2" dia. up. Tygon cut or molded gaskets provide pressure tight, corrosion-resistant seals; Tygon molded mechanical goods items can be made to virtually any shape and in a wide range of hardnesses; Tygon flexible Tubing, in bores up to 3", makes an excellent piping medium for gas, air or liquids.

Tygon Paint, a liquid form of these versatile plastics, provides unexcelled protection for tank exteriors, machinery, walls, and structural steel exposed to the attack of corrosive fumes or acid spillage.

In one or more of their many forms, Tygon Plastics offer the engineer quickly effective ways to keep maintenance costs in check—superior ways to prolong plant and equipment life. If you'd like full data on all the Tygon Plastics, write for the Tygon Portfolio.

181F

PLASTICS AND SYNTHETICS DIVISION . . .

U. S. STONEWARE
Since 1865 • Akron, Ohio

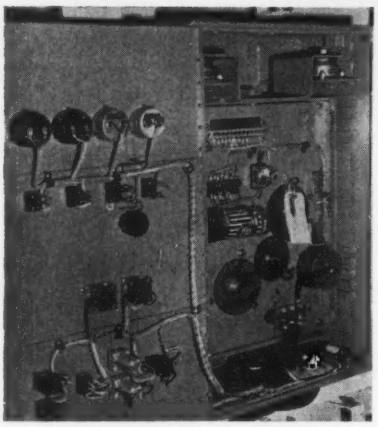


Figure 1—Inside view of automatic control center used to maintain a pre-set potential voltage on the ship's hull.

Automatic Control of a Platinum Anode Cathodic Protection System*

Roy C. Francis and Leon S. Birnbaum
Bureau of Ships, Navy Department
Washington, D. C.

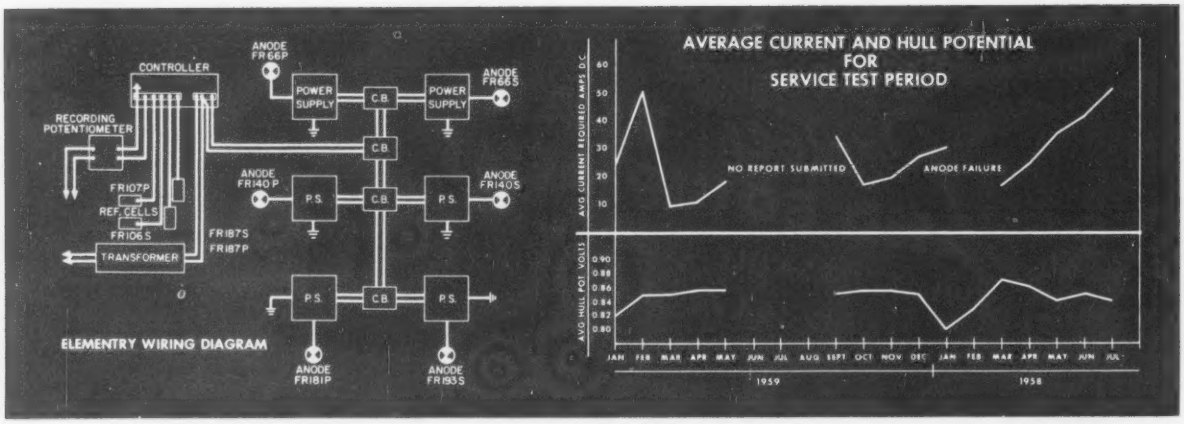


Figure 2—Wiring diagram of automatically controlled cathodic protection system for the USS Blandy.

Figure 4—Average current and hull potentials during service test period.

OPERATIONAL TESTS of an automatically controlled impressed current cathodic protection system on a new U. S. Navy destroyer have shown that such a system effectively controls corrosion. Improvements in the system described here are possible.

Economic justification for adoption of an automatic system has not been considered. Because of high initial cost of equipment and installation, savings resulting from reduced repair and maintenance costs caused by corrosion must be evaluated carefully.

Adoption of an impressed current system for standard use on ships would be economically more attractive if a more simplified and less expensive system were developed.

Description of Installation

The automatic cathodic protection system installed on the *USS Blandy* (DD 943) in December, 1957, included the following: six circular platinum-palladium alloy anodes, four silver-silver chloride reference electrodes, six transformer-rectifier power units, an automatic potential recorder, a shaft-propeller grounding assembly and the automatic controller shown in Figure 1.

Anodes

The first anodes used were 6½-inch diameter and 5 mils thick platinum-palladium discs recessed into a glass reinforced polyester mount. Current flow to the disc was through five finger-like platinum-palladium wires dap welded to the disc surface. Because of unsatisfactory service performance, this design was modified to a solid rod stem for the finger-like wires. However, the modified anode failed after five months' service for the following reasons:

1. Improper weld between disc and stem for operating condition encountered.
2. Insufficient thickness of foil at stem contact point used because of economic considerations.
3. Lack of sufficient bond between disc and plastic mount.
4. Hydrodynamic characteristics of design.

These four weaknesses were eliminated by avoiding a recessed foil, by using 10-mil foil with 20-mil reinforcement at the stem-disc junction and use of heliarc welding. Design also was modified to improve bond between disc and mount and to give more suitable hydrodynamic characteristics.

An eight-foot square neoprene rubber dielectric shield (⅛-inch thick) was cold bonded to a sandblasted surface about each anode.

Reference Electrodes

The type reference electrode used consisted of a silver-silver chloride half-cell enclosed in an 8-inch diameter unplasticized vinyl holder. The half-cell element was made of silver wire gauze coated with silver chloride and provided a continuous signal voltage to the d-c input circuit of the power supply.

Power Units

One power supply unit was located inside the ship hull as close to each anode as possible. Each unit consisted of a transformer, rectifier and an ammeter to read direct current to each anode. Each unit had primary and secondary transformer taps for differential current adjustment.

Potential Recorder

An automatic potential recorder was used to provide continuous, single point recording of hull potential at any one of the selected hull mounted reference cells.

★ Revision of a paper titled "Service Test Experience With an Automatically Controlled Platinum Anode Cathodic Protection System of an Active Destroyer" presented at the Northeast Region Conference, National Association of Corrosion Engineers, October 5-8, 1959, Baltimore, Md.

Shaft Grounding Assembly

A positive hull-to-shaft ground was obtained by a bronze slip ring, brush holder, copper bus bars and brushes. Silver-graphite brushes were used to insure a low resistance path for current flowing to the propellers to return to the hull. The slip ring was electrically coupled to the nearest shaft flange by copper bus bars.

Automatic Controller

The automatic controller as shown in Figure 1 was an electro-mechanical type containing relays, meters, motors and other necessary components to maintain a pre-set hull potential based on signals from the hull mounted reference electrodes. This was accomplished by controlling the alternating current to the individual power supply units.

Principles of Operation

Principles of operation for the automatically controlled protective system can be described briefly as follows (see Figure 2): The selected reference electrode furnishes a signal voltage of the hull potential to the d-c input circuit of the power supply. A timing device periodically compares the reference electrode voltage to a pre-set voltage. A difference between these two voltages (indicating that the hull is not at the desired potential) causes the power supply to adjust its output so that the hull will have the desired potential.

This automatic feature of the system is accomplished by successive step changes in output voltage, each step change occurring after the input is sampled. The step changes continue at approximately one-minute intervals until the desired hull potential is reached, thus eliminating the difference between the reference electrode and the pre-set voltages.

First Tests at Sea

When the ship went to sea in January, 1958, for sea trials and routine drills, operation of the automatic cathodic protection system was checked.

At a speed of five knots and before the system was energized, hull potentials were measured with portable equipment to establish a baseline for protection required. Protection usually is considered adequate when the hull potential is —0.2 to —0.3 volt more negative than the hull's natural potential without cathodic protection. A protective potential was obtained in 20 minutes after energizing the system.

Hull-to-propeller current measurements also were taken while the ship was underway with the protective system energized and turned off. A current flow of 4.2 amperes was recorded at 10 knots when the protective system was off. This current flow did not increase appreciably with increase in speed. However, identical measurements showed that current flow to the port propeller with the protective system energized increased 2.4 times at 10 knots and 4 times at 15 knots. These measurements suggested that the greater portion of current required to maintain hull potentials were being used by the bronze propeller. This current flow increased with increased speed.

Current requirements of the hull to maintain a pre-set potential were affected only slightly by increased speed. During a speed increase from 5 to 20 knots, a d-c current increase of only 5 amperes was indicated.

First Inspection in Drydock

The ship was drydocked after eight months' service. The hot plastic paint system used on the hull was in good condition except in limited areas. The coating was missing on both sides of each rudder and from the trailing and leading edges of the main struts and strut barrels as shown in Figure 3. But there was no general corrosion or pitting on these bare areas.

The initially installed anodes were replaced with the modified type described above.

Stray Current Tests

Twelve silver-silver-chloride reference electrodes were distributed around the ship for stray current tests to determine the effect of welding. Hull potentials were measured while welding was in progress and also after welding had stopped. During the daytime working hours, potentials fluctuated between 0.68 and 1.40 volts, depending on the extent of welding on the *Blandy* or on other ships in the vicinity. When welding was not in progress, hull potentials approached the natural hull potential (0.55 to 0.70 volts). These measurements were made with the cathodic protective system secured.

Stray currents from sources other than welding on the *Blandy* were checked by metering a known current from the welding generator to the hull through a bank of resistors. The welding ground return from the ship to the generator was not interrupted. Clip ammeter readings at the welding return lead showed 75 amperes increase in current returning to the welding generator over that supplied to the ship. This increase was considered to be stray currents flowing through the ship's ground return. Current apparently originated from other welding operations or shipyard work and were conducted through the water to the ship's hull, resulting in relatively high fluctuating hull potentials. Some of the stray currents probably passed from the ship's hull to the pier structure because the welding equipment was grounded in some manner to the pier. This is objectionable and can cause serious paint damage and hull corrosion if allowed to continue for any length of time.

Abstract

Gives description of components used for automatically controlled cathodic protection system on U. S. Navy ship using platinum-palladium alloy anodes, silver-silver chloride reference electrodes. Briefly gives principles of automatic operation by which hull potential voltage is maintained at pre-set level. Also includes discussion of stray current and mooring problems encountered. Explains that system operated satisfactorily, protecting the ship hull from corrosion even though coating system had failed and left bare hull areas exposed. 5.2.1

Second Hull Inspection

During its second drydocking in March, 1959, the ship's hull was in excellent condition although all operating anodes had failed because the stem had been separated from the disc. (Two of the six anodes were previously disconnected to balance current distribution.)

The hot plastic paint system was about 95 percent intact. Isolated bare areas on the hull showed only superficial rust which was easily removed with the hand. Appendages also were in good condition with the exception of the port propeller.

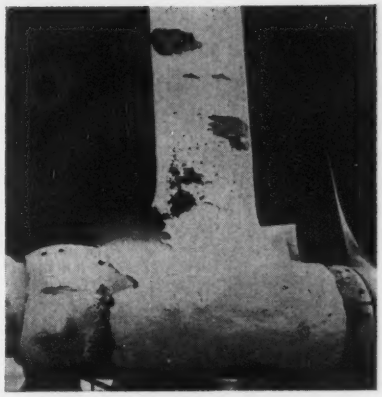


Figure 3—Plastic coating failure on main strut and barrel on port side. Although coating failed, the bare areas were cathodically protected.

This propeller showed one relatively large pit (⅛-inch deep) and several smaller ones on the forward leading edge of one blade about four inches from the hub. Etching also was noted at the blade ends. The starboard propeller was only slightly etched at blade ends with no pitting observed. Difference in condition between the two propellers was attributed to the fact that the grounding assembly was inoperative on the port shaft for an indefinite period.

Current Requirements

Average current requirements and hull potentials over the 18-month service test period are shown in Figure 4. Except for January and February, 1959, when only two anodes were operating, hull potentials were maintained between 0.84 and 0.87 volts.

Mooring Problems Encountered

Operational experience with the automatic system on the *USS Blandy* indicated the difficulty of isolating a Navy ship with cathodic protection installed from one that has no system. Although it is considered better to electrically bond ships so that adjacent ships can be partially protected, this procedure can overload the cathodic protection system. But if a positive bond is not maintained, stray currents from the cathodically protected ship can damage adjacent ships.

Thus, the *Blandy* was required to operate its system at a 0.80 volt potential while moored. This is considered to be a setting low enough to meet the minimum hull requirements of the protected ship and, when bonded, to adjacent ships, to minimize overloading the system.

The flow of stray currents in cathodic protection of ships is an area which requires further study.

Bibliography

1. H. S. Preiser and B. H. Tytell. Some Platinum Anode Designs for Cathodic Protection of Active Ships. *Corrosion*, 15, 596t (1959) November.
2. L. J. Waldron, M. H. Peterson and M. C. Bloom. Cathodic Protection for Naval Vessels—Experimental Studies. *Corrosion*, 15, 87 (1959) February.
3. Irving D. Gessow. Navy Experimental Work With Cathodic Protection. *Corrosion*, 12, 100t (1956) March.
4. K. N. Barnard and G. L. Christie. Cathodic Protection of an Active Ship in Sea Water. Part I. *Corrosion*, 6, 232 (1950) July. Part II: *Corrosion*, 7, 144 (1951) April.
5. E. E. Nelson. An Impressed Current Cathodic Protection System Applied to a Submarine. *Corrosion*, 13, 122t (1957) February.

(Continued on Page 22)

Automatic Control–

(Continued From Page 21)

6. H. S. Preiser and F. E. Cook. Cathodic Protection of an Active Ship Using a Trailing Platinum Clad Anode. *Corrosion*, **13**, 125t (1957) February.
7. E. C. Reichard and T. J. Lennox. Shipboard Evaluation of Zinc Galvanic Anodes Showing the Effect of Iron, Aluminum and Cadmium on Anode Performance. *Corrosion*, **13**, 410t (1957) June.
8. B. H. Tytell and H. S. Preiser. Cathodic Protection of an Active Ship Using Zinc Anodes. *Corrosion*, **13**, 515t (1957) August.
9. R. C. Francis. Zinc Anode Cathodic Protection System on the *USS Wahoo*. *Bureau of Ships Journal*, **7**, 14-17 (1959) April.

DISCUSSIONS

Questions by Charles Frank Schrieber, Dow Chemical Co., Freeport, Texas: What was the average current density on the underwater area? Have you tried zinc as a reference electrode?

Reply by R. C. Francis:

The *USS Blandy* has a witted surface area of about 20,000 square feet. Average current output of the cathodic protection system for the entire period of operation was 27 amperes giving an average current density of 1.3 milliamperes per square foot. Highest current density attained during the 19-month period was 4.5 milliamperes per square foot. In this connection the data presented and that obtained since then indicate that from 2 to 5 times more current is required to maintain protective potentials with grounded shafts and propellers than without such grounding, depending on ship speed.

Zinc has not been tried as a reference electrode on active Navy ships. However, some test work has been done by the Naval Research Laboratory in connection with reserve fleet ships using zinc as a reference electrode. Results to date indicate that if filming of the zinc can be prevented, it should be a satisfactory reference where high accuracy is not required.

Question by Ramond F. Vines, International Nickel Co., Inc. New York, New York: The fact was mentioned that paint was missing from the hull. Would the authors comment on the reason?

Reply by R. C. Francis:

At both drydocking inspections, the hot plastic paint system was in very good condition. As would be expected, the stern appendages, docking block positions and sea chests suffered the worst paint damage. Paint failure on appendages and sea chests may have been due to turbulent water flow or other normal causes. Docking block areas were bare apparently because paint was not applied at the previous drydocking. No bare areas were considered to have resulted from the cathodic protection system except possibly some very small spots about the edge of the neoprene dielectric shields. The most significant point is that there was not pitting or general corrosion.

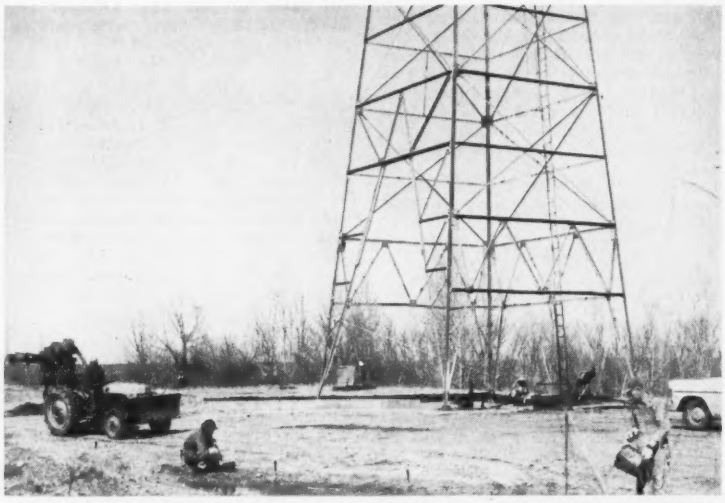
Comments by Thomas P. May, Wrightsville Beach, North Carolina: Tests at Inco's Kure Beach-Harbor Island Test Station of dapweld and target anodes in 30 mph water and 30 amps have shown that the damage on dapweld anodes is substantially machanical, possibly fatigue failure. This damage which is unrelated to energized versus not-energized anodes has not occurred on all installations. No failures have occurred on target type anodes. It may develop from distortion of the plastic support during mounting on curved surfaces of a hull or may be due to lack of proper control during fabrication. End result is a relatively loose platinum foil that flutters when a ship is underway. This flutter apparently causes fatigue failure at the center near the dapweld. No chemical or electrochemical damage should occur at the operating current densities (up to 100 ASF) before failure because tests have revealed that the 80-20 Pt-Pd alloys suffer little corrosion even at current densities at 500 ASF. However, some electrochemical damage may possibly occur at the end of the center rod after the break because the current density may then greatly exceed 500 ASF which is the highest density that has been studied.

Reply by R. C. Francis:

Naval Research Laboratory tests indicate that electrochemical action may also have contributed to the failures. It is interesting to note that all four of the energized solid rod type anodes failed from three to five months after installation. The two anodes which were not energized during this period did not fail.

The fact that the anodes failed, however, not only on this ship but others also, was sufficient for rejection of this design as unsatisfactory.

The target design has been in service approximately eight months and appears to be a considerable improvement over previous anodes. Time will tell whether this design is sturdy enough to withstand the stresses of the sea.



"CONSTANT CURRENT" RECTIFIERS STOP WELL CASING CORROSION

New "constant current" rectifiers were used to stop casing corrosion on 29 wells in West Texas recently. The wells are owned by a major oil company and are in Borden County.

Several casing leaks had already occurred in the field. The operator felt that protection was necessary.

CSI engineers installed rectifiers to provide the electrical current which is projected onto the casing to stop external corrosion. CSI furnished the rectifiers and all the other necessary materials, labor and installation equipment—augers, ditchers, etc. Cost was only about $300 to $350 per well.

The rectifiers used are of a recently developed kind that, for all practical purposes, deliver constant current despite heavy rains or extended dry periods. They compensate automatically for changes in current resistance caused by variations in the moisture content of the soil.

CSI expert and experienced engineers are your key to the best in cathodic protection for wells, transmission and distribution pipe lines, tanks, etc. Call or write today for engineering and installation services, and for quality supplies for both magnesium anode and rectifier installations. Prices are competitive.

CSI

Cleveland 13, Ohio
1309 Washington Ave.
Tel. CHerry 1-7795

CORROSION SERVICES INCORPORATED
General Office: Tulsa, Okla.
Mailing Address:
Box 787, Sand Springs, Okla.
Tel. Circle 5-1351

CLEANED SAFELY WITH PFIZER CITRIC ACID

STAINLESS STEEL BOILERS, HEAT EXCHANGERS, ATOMIC INSTALLATIONS, CHEMICAL PROCESSING EQUIPMENT CLEANED SAFELY, EFFICIENTLY WITH PFIZER CITRIC ACID

● Industry experience proves that citric acid eliminates chloride stress corrosion problems — provides effective descaling — permits easier, more efficient after-rinsing.

Discuss with your chemical cleaning service company these advantages of Pfizer Citric Acid in stainless steel cleaning solutions:

1 Citric acid is highly efficient in removing imbedded metal and oxide films from stainless steel.

2 Citric acid's excellent sequestering ability prevents reprecipitation of dissolved scale.

3 Citric acid cleaning eliminates the problem of chloride stress corrosion.

4 Citric acid can be effectively inhibited without losing its cleaning or sequestering ability.

5 Citric acid is sold as a dry, 100% acid — meaning savings in storage and handling.

6 Citric acid is water soluble, easy to handle, and non-toxic.

Let us send you further information, cost and obligation-free!

I want to learn more about the use of Pfizer Citric Acid for cleaning stainless steel equipment. Please send me Technical Bulletin 102.

Name_____

Company_____

Address_____

City_____ Zone____ State_____

Science for the world's well-being

Manufacturing Chemists for Over a Century

Pfizer

CHAS. PFIZER & CO., INC., CHEMICAL SALES DIV., 630 FLUSHING AVE., BROOKLYN 6, N. Y.
Branch Offices: Clifton, N. J.; Chicago, Ill.; San Francisco, Calif.; Vernon, Calif.; Atlanta, Ga.; Dallas, Tex., Montreal, Canada

NEW RUST-BAN® 190

Now you can get offshore corrosion protection with remarkable economy, measured by cost per year of satisfactory service. • *New* Humble RUST-BAN 190, a 100% inorganic zinc silicate coating, actually reacts with steel to form an inseparable bond with the surface. Because of this interaction, RUST-BAN 190 affords excellent adhesion to give you a hard, abrasion-resistant coating that lasts for years. • Underfilm corrosion is eliminated. Scraping or impacts cannot break the coating to cause failures. • And RUST-BAN 190 contains no lead, is non-toxic and non-flammable. • For complete information, call your Humble salesman or contact Humble Oil & Refining Company, Houston, Texas.

HUMBLE OIL & REFINING CO. HUMBLE

Corrosion-Interest Papers to Be Given At Plastics Meeting

Several papers of probable interest to corrosion engineers will be given at the January 24-27 conference of the Society of Plastics Engineers, Inc., to be held in Washington, D. C.

These papers are as follows: Pitfalls in Predicting the Performance Characteristics of High Density Polyethylene, Moisture Resistant Coatings for Class B Printed Circuitry, Improved Reliability for Printed Circuits with Protective Coatings, Simplified Analysis of Filament Reinforced Plastic Pressure Vessels, Glass Reinforced Plastic Aviation Gas Turbine Compressor Housing, Promotion and Retardation of Cross-Linking in Thermally Processed Polyvinyl Chloride Systems, New Cross-Linkers for Furfuryl Alcohol Resins, Chemically Cross-Linked Polyethylene, Study of Maleate and Fumarate Polyester Resins.

Effect of Finishes on Heat Resistant Phenolic and Modified Epoxy Laminate Systems, Processing Characteristics and Applications of Estane Thermoplastic Polyurethanes, Polyvinylidene Fluoride RC-2525, New Techniques in Applying Epoxy Trowelling Compounds, Research and Development of High Temperature Stable Polymers, Processing Variables and Their Effects on Properties of Coatings Made With Polyethylene, Polypropylene and Nylon 6, and Mechanics and Testing of Plastisol Gelation and Fusion.

English Corrosion Group Schedules Godard Paper

The Corrosion Group of the Society of Chemical Industry, 14, Belgrave Square, S.W.1., London, England, will have a paper by Hugh P. Godard, past president of NACE, of Aluminium Laboratories, Ltd., Kingston, Ontario, Canada, at its March 28 meeting to be held in Banbury. The paper will be on aluminum's resistance to supply waters. Another paper on aluminum's behavior in modern power station condensate water by E. A. G. Croom and D. Hastings also will be presented at the meeting.

Other meetings scheduled by the Corrosion Group are as follows: January 18: Metallic diffusion coatings, by R. L. Samuel. February 14: Occurrence of fire-side corrosion in modern steam generators, by W. D. Jarvis and D. B. Leason. February 28: Cathodic Protection Panel Meeting and a paper on external protection of floating craft by M. G. Duff. March 7: Metal spraying for protection of bridge structures, by J. D. Thompson.

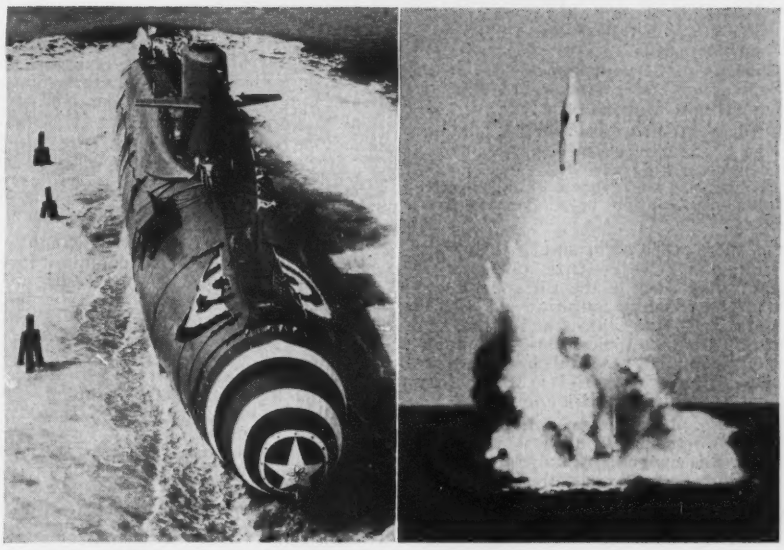
High Temperature Meeting

A symposium on measurement and control of temperature will be held March 27-31 in Columbus, Ohio. About 200 papers will cover temperature measurements from absolute zero to 10 million K. The conference is sponsored by the American Institute of Physics, Instrument Society of America and the National Bureau of Standards.

•

Most of the 85,000 channel miles of the United State's television facilities are equipped for color transmission.

RECORD and REPORT



GALVANIC CORROSION attack on the air valves controlling ejection of the Polaris missile delayed repair on the U.S.S. Patrick Henry, second of the U. S. Navy's ballistic missile firing atomic submarines. This 380-foot, 5400-ton vessel was designed to carry the Polaris missile, which can be fired from below the ocean's surface (shown at right).

Dock-Side Plating Job Solves Sub's Galvanic Corrosion Problem

Selective plating in place, an advanced brush plating technique, saved several months' repair time recently for the atomic submarine U.S.S. Patrick Henry, which had been held up because of galvanic corrosion attack on the compressed air valves which control ejection of the Polaris missles fired by the submarine.

Removal of the valves from the atomic submarine at its home port in Connecticut and shipping them for repairs to the west coast manufacturer would have meant a delay of several months.

The Navy Department's Special Projects Office, in charge of the Polaris submarine program, worked with Marlane Development Co., Inc., New York City, and Metachemical Associates, Inc., 70-49A Austin St., Forest Hills 75, N.Y.

From experience, engineers knew that 25 percent or more of indium imparts exceptional resistance to salt water corrosion. They suggested plating corroded areas of each valve with an alloy of tin and indium.

To facilitate the operation, the Navy removed the valves from the submarine to a barge alongside. An area totaling approximately 750 square inches on each valve was plated with about 3 mils of tin-indium alloy. Valve throats which open on the launch tubes were given a 2-mil plating. Threads inside these throats were flash plated.

A mobile power pack converted 220-volt a-c line current from the dockside to direct current. A continuously variable voltage regulator was set to provide optimum current density (to 5000 amp per square foot) for rapid alloy deposition. Three leads were connected to the rectifier: a cathode clamped to the work piece and two anodes to which the special plating styluses were attached.

Machined from graphite in an oblong spatula shape, the stylus tips were covered with absorbent cotton which was dipped into a solution containing plating alloys or cleaner as required and then rubbed gently on the valve surface to be plated.

After the flange, throat and valve cavity had been plated, Navy engineers discovered additional corrosion where packing contacted the poppet shaft below the cavity. Poppets had to be removed so that the wall could be plated.

All the plating work was completed in only 3½ weeks.

Abstract Microcards

The American Chemical Society recently signed a contract with the Microcard Corporation for microcard reprinting of the first decennial index to Chemical Abstracts for the years 1907 to 1916.

This index will be re-issued in conventional form and on microcards as an experiment to test the demand for the latter medium.

BOOK NEWS

Proceedings, Short Course on Process Industry Corrosion. Edited by V. D. Miller. 448 pages, 8½ x 11, paper cover, plastic back. 1960. The National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas. Per copy, NACE Members $20; nonmembers, $25.

Consists of 21 papers presented at the September 12-16, 1960 course held at Ohio State University, Columbia by Dept. of Metallurgical Engineering, College of Engineering and Technical Group Committee T-5 on Corrosion Problems in the Process Industries, National Association of Corrosion Engineers.

Papers are: Corrosion in Alkaline Environment; Use of Iron, Carbon Steel and Alloy Steel in the Chemical Industry; Corrosion by Sulfuric Acid; Copper and Its Alloys, Classes and types, Corrosion Characteristics and Applications; Nickel and High-Nickel Alloys; Corrosion From Chlorine—Its Major Compounds and Their Homologs;

Corrosion by Acetic Acid; Solving Refinery Corrosion Problems With Aluminum; Resistance of Aluminum Alloys to Underground Corrosion; Corrosion Studies of Aluminum in Chemical Process Operation; Use of Tantalum, Columbium, Titanium and Zirconium in Chemical Environments; Materials for Handling Hydrofluoric, Nitric and Phosphoric Acids; Corrosion Problems in Industrial Cooling Waters;

Designing Corrosion Out of Process Equipment; Materials for Low Temperature Use; Steels in High Temperature Service; Corrosion Testing; Rigid Plastics for Corrosion-Resistant Applications; Protective Coatings for Chemical Service; Notes on Evaluation and Measurement of Various Modes of Corrosion Damage; Waterside Corrosion in Steam Plants.

The book is liberally illustrated and referenced.

Proceedings, Fifth Annual Appalachian Underground Short Course (1960). Edited by R. E. Hanna, Jr. 538 pages, 6 x 9 inches, paper. October, 1960. Tech. Bul. No. 59, Engineering Experiment Station, West Virginia University, Morgantown. Price not indicated.

Consists of 58 lectures presented during the Fifth Appalachian Underground Short Course held at Morgantown, W. Va. June 1-3, 1960. The papers are divided into the following categories: Basic, intermediate (pipe), intermediate (cable), advanced, public water systems, pipe coatings, instruments, special topics (internal coating of pipelines, protection of storage wells, reference electrodes, microbial development, stray currents); outlines of field demonstration procedures.

The collection represents a comprehensive review, plus considerable information on new methods, materials and processes of underground corrosion and mitigation methods. The book is liberally illustrated.

High Purity Water Corrosion of Metals. Edited by Norman E. Hamner. 100 pages, 8½ x 11, typescript; paper back, plastic binding. October, 1960. National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas. Per copy, postpaid, NACE members, $7; non-members, $9.

Seven papers presented at symposia during meetings of the National Association of Corrosion Engineers during 1959 and 1960. The papers are: Corrosion of Aluminum-Nickel-Iron Alloys in High Temperature Water by J. G. Biefer and F. H. Krenz; Susceptibility of AISI 410 to Stress-Corrosion Cracking in High-Temperature High Purity Water by Henry Suss; Corrosion of Metallic Materials in High Temperature Pile-Irradiated Water by G. E. Galonian;

Corrosion of Carbon and Low-Alloy Steel in Out-of-Pile Boiling Water Reactor Environment by D. C. Vreeland, G. G. Paul and W. L. Pearl; Use of Neutron-Activated Specimens for the Study of Corrosion Products Release Rates by G. P. Simon; Corrosion Study of Metals for Superficial Pressure Power Plants by R. C. Ulmer; Aluminum Alloys for Handling High Temperature Water by M. H. Brown, R. H. Brown and W. W. Binger;

There is a bibliography of papers on corrosion by high purity water published in CORROSION magazine.

Ultrasonic Welding. Arthur L. Phillips, editor. 38 pages, 6 x 9 inches, paper. 1960. The American Welding Society, 33 West 39th St., New York 18, N.Y. Price not indicated.

Reprinted from Section II of The Welding Handbook. Contains the following sections: Fundamentals of process, base metals welded, welding techniques, weld characteristics, quality control, equipment, application, bibliography and index.

Haufige Korrosionshaden an Metallen und Ihre Vermeidung. In German. Common Corrosion Damage to Metals and Its Prevention. By G. Schikorr, 146 pages, 5¾ x 8¼ inches, paper. 1960. Published by Konrad Wittwer, Stuttgart, Germany. Price not indicated.

This is Volume 3 in a series of books by the Baden Wurttenburg Industrial Commission. It discusses corrosion behavior of the common metals with chapters on galvanic, atmospheric corrosion; corrosion by building materials, water, soils, foods, fuel oil, combustion gases and fibrous materials.

There is a list of titles of 36 books on corrosion including 13 in English, 21 in German and two in Czech. There are 520 references, constituting a good introduction to European corrosion literature. Schikorr is considered a world authority on corrosion.

The book also includes a section on analysis and diagnosis, a subject index and a section devoted to pictures of corroded articles.

The Air Pollution Problem—An Appraisal. By W. L. Faith. 35 pages, 6 x 9 inches, paper. November, 1960. Air Polution Foundation, 2556 Mission St., San Marino, Cal. Availability not indicated.

A pamphlet concisely summarizing the nature and extent of the air pollution problem. Governmental and non-governmental control measures are reported. The principal problems related to air pollution are summarized.

Standards of the Hydraulic Institute. Tenth Edition. First Revision. 75 pages, 8½ x 11, loose leaf. Nov. 18, 1960. Hydraulic Institute, 122 East 42nd St., New York 17, N. Y. Per set $1.25.

Loose leaf pages intended for insertion in the 1955 edition of the standards. Those who have the basic book may bring it up to date with these new pages. The changes affect flooded, suction, specific speed and self-priming pumps; dimensions of NEMA Tye C face-mounted motors; shaft extension dimensions for NEMA Type P verticle solid shaft AC motors; NPSH charts for centrifugal hot water pumps, single and double suction; revisions of the test code for centrifugal pumps; calculation of volumetric efficiency of reciprocating pumps.

Those who want a complete copy of the revised standard may be get it for $6 for domestic addresses; $6.50 foreign.

LET *Coreco* WORK FOR YOU 24 HOURS A DAY TO PROTECT YOUR OIL OR WATER STORAGE TANKS AGAINST COSTLY CORROSION . . .

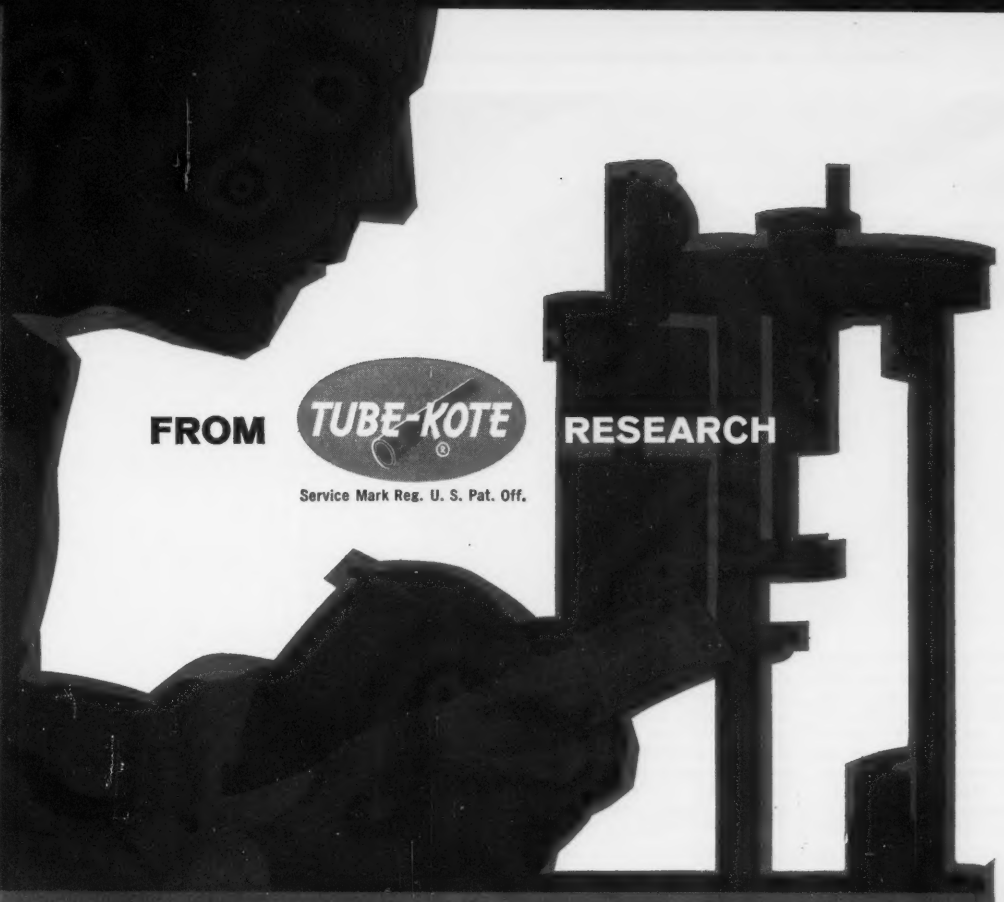
Two-fisted Coreco protection pays for itself many times. Whether your problem is better solved by rectifiers or magnesium anodes, our engineers have the knowledge to determine lowest overall installation and operating costs. It costs you nothing to check with Coreco engineers.

Coreco

Write or phone today for COSTS • SURVEYS • DESIGNS INSTALLATIONS • MATERIALS

Corrosion Rectifying Co., Inc.

5310 ASHBROOK • MO 7-6659
HOUSTON 36, TEXAS



FROM TUBE-KOTE® RESEARCH

Service Mark Reg. U. S. Pat. Off.

THE INDUSTRY'S MOST COMPLETE SELECTION OF

COATINGS FOR YOUR SPECIFIC NEEDS

Tube-Kote research has pioneered and developed new plastics to meet the specific needs of high pressures, temperatures, impact, flexibility and different types of corrosive environments.

Specialized T-K Coatings are custom manufactured by Tube-Kote in their own plant. The result is better coatings for the more severe requirements.

For 21 years T-K Coatings have been performance-proved in both domestic and foreign operations and in practically all corrosive environments.

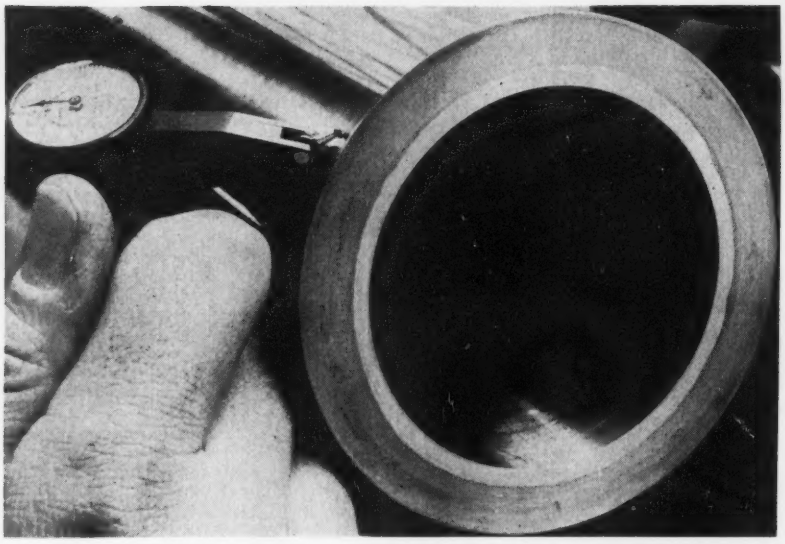
Free Survey

Let a Tube-Kote representative analyze your particular needs and recommend a coating to fit the situation, or send for Free, Informative Book, "Coatings for Corrosion and Paraffin Control."

TUBE-KOTE®

Our 21st Year... the Industry Pioneer

P. O. Box 20037 Houston 25, Texas
Branch Plants: Harvey, Louisiana; Midland, Texas



COMPOSITE TUBING made of stainless steel and carbon steel to resist two different corrosive medias at the same time: stainless steel on the tubing interior to resist corrosion from the coolant in a reactor's fuel system and carbon steel on the outside to resist atmospheric conditions. Tests have shown that a metallurgical bond of high strength is formed between the two types of steel, Stainless steel was specified for the primary side of the reactor because of the steel's corrosion resistant qualities. Carbon steel permits a strong weld of the tubing to the reactor structure. The metallurgical bond eliminates possibility of a corrosive medium seeping between the liner and the outside carbon steel. The tubing was produced for Standard Pressed Steel Company of Jenkintown, Pa.

Nickel-Aluminum Alloy Coatings Control Oxidation at 1000 F

A method for producing nickel-aluminum alloy coatings capable of protecting metals from oxidation at temperatures to 1000 C has been developed by the national Bureau of Standards in a program sponsored by the Wright Air Development Center. The coatings can be used to advantage on many types of aeronautical equipment. The most durable coating was obtained by electroplating nickel over the basis metal and then plating aluminum on the nickel at 700 C.

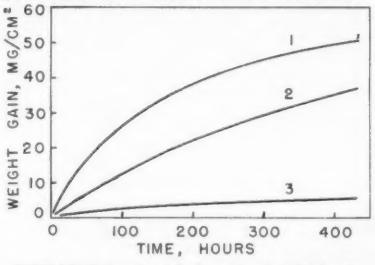
Although cast nickel-aluminum alloys have good corrosion resistance to atmospheric exposure and maintain hardness at elevated temperatures, brittleness prevents their being fabricated into intricately shaped parts. However, by utilizing the alloy as a coating rather than as a basis metal and by electroplating it on more ductile metals, an effective corrosion resistant material can be obtained.

The accompanying graph compares oxidation of nickel and nickel-aluminum alloy coatings at 1000 C.

To find suitable plating conditions for producing a smooth, oxidation resistant nickel-aluminum coating, D. E. Couch and J. H. Connor of the Bureau's electrodeposition laboratory studied aluminum plating baths prepared from organic solvents or fused salts.

The most satisfactory procedure consisted in electrodepositing nickel from a Watts type of bath (a mixed chloride-sulfate bath), and then electroplating aluminum on the nickel layer. The aluminum was deposited from a fused salt solution containing a mixture of potassium chloride, sodium chloride, and cryolite (sodium aluminum fluoride) at 700 C. At this temperature, aluminum diffuses into the nickel layer, as it deposits, thus forming the alloy.

In the cryolite deposition, samples plated with nickel were placed in the bath in a graphite container and allowed to heat up to bath temperature before electrolysis. Excellent adhesion was obtained on nickel and on previously prepared nickel-aluminum alloys. At 700 C, an aluminum deposit (0.00025 inch thick) was produced by using a current density of 7 amps/dm² for 5 minutes. However, when the electrolysis was continued under these conditions for a longer period, the aluminum was deposited faster than it could diffuse into the nickel. Excess aluminum dripped off the bottom of the sample. Thicker deposits could be produced by using a lower current density for a longer time or by operating at a higher temperature.



OXIDATION of nickel and nickel-aluminum alloy coatings at 1000 C are compared in this graph. The nickel-aluminum alloy coating was developed by the National Bureau of Standards for protection from oxidation at temperatures to 1000 C. Curve 1 is pure nickel, Curve 2 is the alloy coatings (about 0.0003 inch thickness) and Curve 3 is the alloy coating also (about 0.001 inch thickness).

For objects which require coatings but which cannot withstand the high temperature necessary to operate the cryolite bath, an alternate method for plating aluminum is used. In this procedure, aluminum is deposited over the nickel at 160 C from a fused salt bath consisting of aluminum chloride and sodium chloride and then alloyed with the nickel by heating for a few hours at 500 to 600 C in air.

Steel specimens coated with the aluminum-nickel alloy were tested in salt spray, in outdoor exposure and in air at elevated temperatures. In air at 550 and 1000 C, alloy coatings oxidized at one-tenth the rate of nickel coatings of comparable thickness. In salt spray tests, panels plated from the cryolite bath were the most durable. Steel panels coated with 0.002 inches of nickel and 0.0005 inches of aluminum withstood 300 hours in salt spray tests before showing rust. Also, rapid thermal cycling of these panels between room temperature and 550 C did not affect their corrosion resistance.

The coatings were more resistant when the aluminum thickness was less than 50 percent of the total coating thickness. Corrosion studies conducted on atmospheric exposure racks correlated well with the salt spray tests. Alloy coated panels did not show rust at the end of one year. In comparison, nickel plated controls rusted after four months.

The coatings provide suitable protection for steel, nickel and molybdenum,[3] and are probably applicable to other metals. Coatings of 0.002 inch thickness protected steel from oxidation at 550 C but did not afford adequate protection at 1000 C because iron diffused through the coating. Thicker coatings probably would be satisfactory.

PIEA and PESA Set Dates For 3 Years' Conferences

Convention cities and dates for the next three years have been set for the Petroleum Industry Electrical Association (PIEA) and Petroleum Electric Supply Association (PESA).

The 1961 conference and equipment exhibit will be April 11-13 at Galveston, Texas. The 1962 convention and exposition are scheduled for April 10-12 at Dallas, Texas. The 1963 meeting will be in Houston, Texas, April 23-25.

NACE member John D. Trilsch of John D. Trilsch Company, 511 Petroleum Bldg., Houston, Texas, is president of PESA. PIEA president is C. E. Upson of Natural Gas Pipe Line Company of America, Chicago, Ill.

Two Air Pollution Reports

Persons interested in air pollution problems may want to get copies of two more reports issued by the Robert A. Taft Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio. The reports are: Air Pollution in Charleston, South Carolina (Report A60-6) and Air Pollution in Hamilton, Ohio (Report A60-8).

•

In 1959, 50,000 swimming pools were built in the United States. Only 17,000 of these were for use by clubs.

BETTER COATINGS THROUGH RESEARCH

RESEARCH EFFORT: ***To continue improving Plasticap coatings and application methods.***

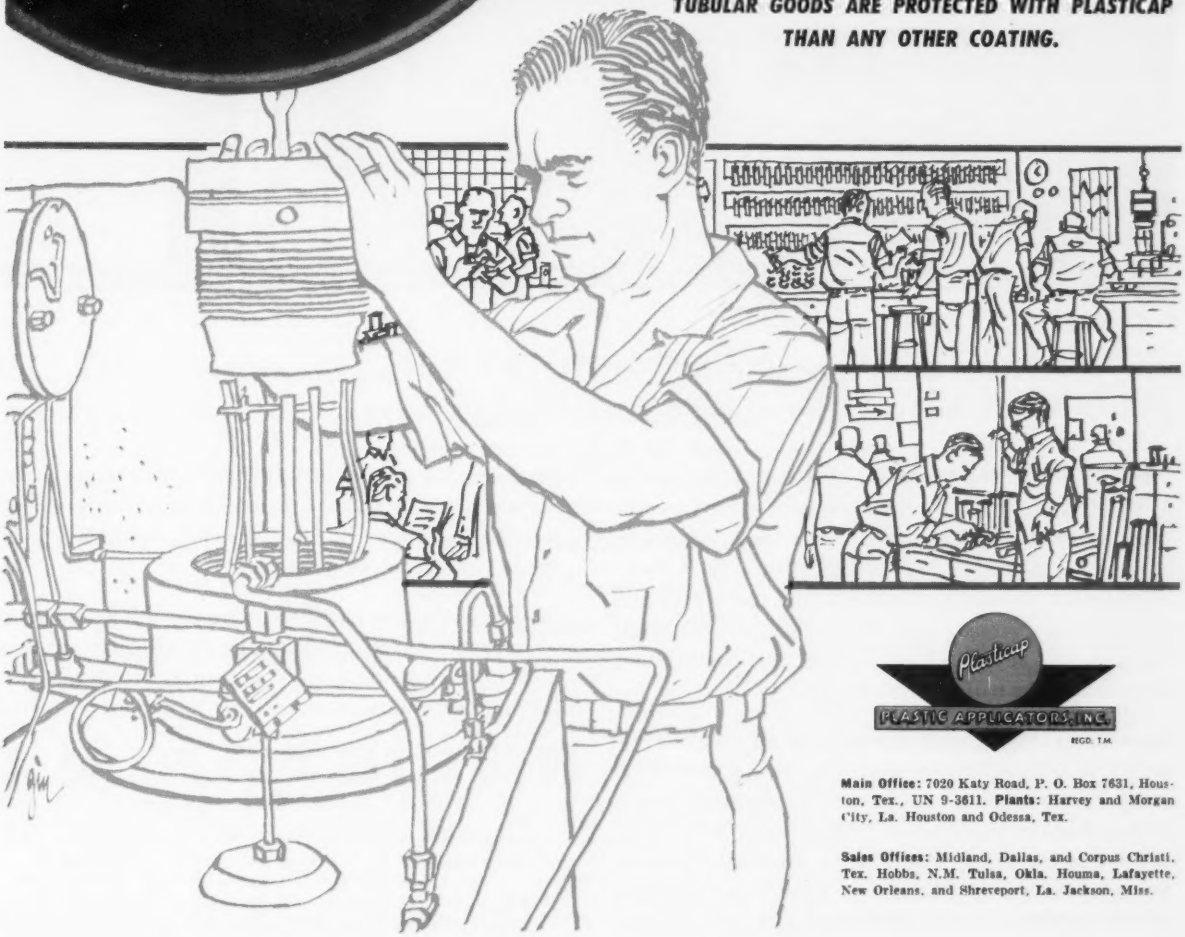
RESULTS: ***A series of successfully completed research projects and an expanded research program. Here are some of these results:***

- Additional new research facilities and personnel have been added recently to augment the continuous research program conducted for years by Plastic Applicators and independent research organizations under contract to Plastic Applicators. Man hours and dollars devoted to research have been constantly increased.

- New coatings developed through this research program have been introduced regularly. Most recent new coating released from the laboratories is Plasticap HTP, which was developed to provide lasting resistance to acids and caustics, even at temperatures above 350°F.

- Air dehydrators have been installed at all Plastic Applicators plants because research has shown that removing all water, oil, and other impurities from air used in the application of Plasticap coatings improves adhesion and resistance qualities of the coatings.

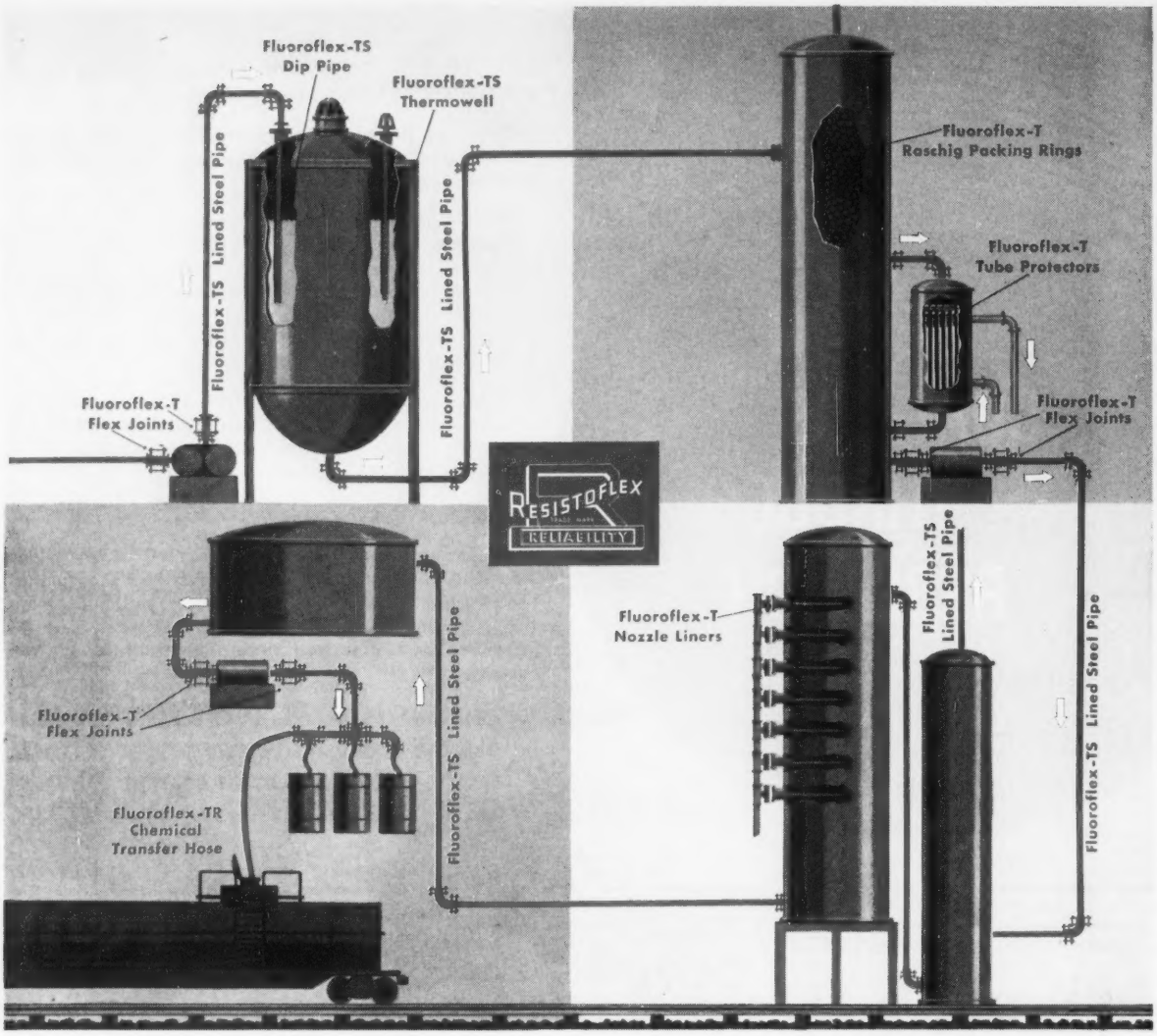
PROTECT YOURSELF AND YOUR PIPE. SPECIFY PLASTICAP. MORE TUBULAR GOODS ARE PROTECTED WITH PLASTICAP THAN ANY OTHER COATING.



Plasticap
PLASTIC APPLICATORS, INC.
REGD. T.M.

Main Office: 7020 Katy Road, P. O. Box 7631, Houston, Tex., UN 9-3611. **Plants:** Harvey and Morgan City, La. Houston and Odessa, Tex.

Sales Offices: Midland, Dallas, and Corpus Christi, Tex. Hobbs, N.M. Tulsa, Okla. Houma, Lafayette, New Orleans, and Shreveport, La. Jackson, Miss.



HERE'S WHY corrosion-proof fluid-handling components of FLUOROFLEX-T (TEFLON) assure production savings, non-contamination:

Fluoroflex®-T Piping Products as shown above can be used with complete and proven assurance that they will not corrode or build up solids which can contaminate sensitive products. Specially processed of Teflon® resins by patented Resistoflex methods, they can handle the most difficult materials up to 500°F. They are completely resistant to any chemical except high-temperature fluorine and the molten alkali metals.

Fluoroflex-T Piping costs no more on an installed-cost basis than other corrosion-proof systems in common use today. Initial material costs have been lowered by recent price reductions made possible by advanced technology and increasing volume. Installation costs are inherently low as a result of skillful design which features easily-bolted-together units with prefabricated, flanged sections.

Fluoroflex-T Piping costs LESS on a performance basis. Savings in operation are assured—with decreased maintenance, long service life, and the elimination of process headaches and downtime.

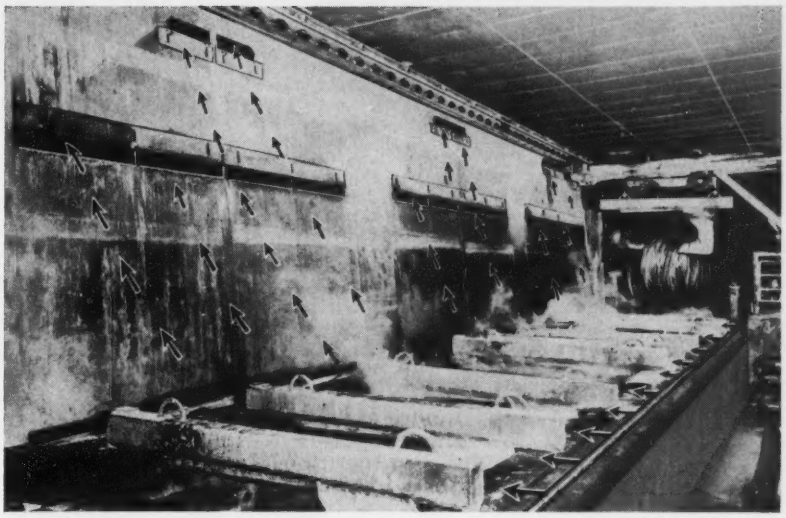
So, if *you* have problems of corrosion—want to reduce maintenance or replacement costs and eliminate process downtime or product loss—consult Resistoflex. Write for more information today.

RESISTOFLEX CORPORATION

Complete systems for corrosive service

Plants **in Roseland, N. J. • Anaheim, Calif. • Dallas, Tex.**
Sales Offices **in major cities**

®*Fluoroflex is a Resistoflex trademark, reg. U. S. Pat. Off.*
®*Teflon is DuPont's trademark for TFE fluorocarbon resins.*



PLASTICS AND AIR were used to solve the corrosion problem around this pickling tank containing 8 percent sulfuric acid at 180 F. Air is blown from the pipe at the lower right to force the acid fumes up to the adjustable louvers in a polyester resin collection hood where the fumes are then exhausted. Glass reinforced bisphenol facing was used on the ceiling panels for protection from the corrosive fumes. The forced air system was designed to eliminate acid fumes from the area where personnel worked.

Polyester Exhaust Hood Resists Sulfuric Acid Corrosion Attack

A combination of a push-pull air flow and a chemical resistant fume collector hood made of reinforced polyester is providing a fume-free work area and is controlling corrosion from a wire pickling bath at the Rock Falls, Ill., Plant of Russell, Burdsall & Ward Bolt & Nut Company.

Previously, serious corrosion attack on structural members of the building and equipment around the bath were experienced. Also, activities of personnel working in the area were hampered by the fumes from the pickling tank containing 8 percent sulfuric acid at 180 F.

As shown in the accompanying photograph, air is forced through holes in a pipe on one side of the tank (at right in photograph) to direct the fumes toward the collector hood and away from the work area. Fume-laden air above the pickling tank is exhausted by suction through the polyester hood.

To prevent fumes from hitting the hood and bouncing back into the work area, a mild flow of air (only 10 cubic feet per minute) is forced from the pipe.

The collector hood, which extends along one side of the tank, has performed for over two years without any sign of deterioration from the sulfuric acid fumes.

Ceiling panels above the pickling tank were faced with a glass reinforced bisphenol for protection from the corrosive fumes.

The installation was designed and fabricated by Heil Process Equipment Co., 12922 Elmwood Ave., Cleveland 11, Ohio. The hood was made of a bisphenol polyester resin called Atlac 382, produced by Atlas Powder Company, Wilmington 99, Del. Cost of the hood was estimated to be half that of a rubber lined steel unit.

Automobile corrosion problems will be discussed in special features scheduled for the February issue.

Industrial Water Corrosion To Be June Meeting Topic

"Corrosion Through Industrial Water" will be the subject of the June 5-7 international meeting on water research sponsored by the European Federation of Corrosion. The meeting will be held at the Palais des Congres, Liege, Belgium. Official languages of the Federation are French, English and German. A special simultaneous interpretation of the proceedings will be made.

Registration information can be obtained from Journees du Cebedeau 1961, 2, rue A. Stevart, Liege, Belgium.

Continuous Sheath Cable Extrusion Now Possible

A continuous extrusion machine has been developed to sheath cable with any lead alloy commonly used. The machine has been tested successfully with arsenical, tin, tellurium, bismuth, antimonial and copper alloys.

Close metallurgical examinations have shown the sheath to be remarkably uniform with no press welds or periodic changes in the sheath because the cable is produced continuously.

This extrusion machine was described in a paper presented recently at a meeting held by the American Institute of Electrical Engineers.

Six Dates Are Set For Training School On Spray Equipment

Dates have been set for six sessions of a training school covering the operation and maintenance of airless spray painting equipment sponsored by the Nordson Corporation, Amherst, Ohio.

The school features instruction in the use and maintenance of airless equipment with emphasis on theory and practice. Sessions cover modern coating materials and their application problems. Classes are divided between lectures and practice work sessions in the Nordson Laboratories.

School dates for the first half of 1961 are as follows: January 10-13, February 14-17, March 14-17, April 11-14, May 9-12 and June 13-16.

Additional information and application blanks may be obtained from the Nordson Corporation, Amherst, Ohio.

Survey of Interest Taken On Soviet-China Abstracts

A survey is being taken by the U. S. Department of Commerce, Office of Technical Services, Washington 25, D.C., to determine the amount of interest for English abstracts of selected articles appearing in the technical journals of the Soviet bloc countries and mainland China. This proposed series would replace the recently discontinued OTS service of providing abstracts of all articles appearing in each issue of certain USSR technical journals. This service was discontinued because of lack of public demand. The new service will not be offered unless demand is sufficient to justify the publication program.

Packaging Course Offered

The ninth annual Purdue University course in industrial packaging will be offered March 20-31 in Lafayette, Ind. The course is designed to give basic knowledge on containers and packaging materials.

Additional information and registration blanks can be obtained from Mark E. Ocker, Division of Adult Education, Memorial Center, Purdue University, Lafayette, Ind.

Gas Turbine Conference

The 6th annual Gas Turbine Conference and Products Show sponsored jointly by the Gas Turbine Power Division of ASME and the U. S. Department of Defense will be held March 5-9 in Washington, D. C.

Feb. 13-16 ASHRAE Meeting

The semi-annual meeting of the American Society of Heating, Refrigerating and Air Conditioning Engineers will be held February 13-16 at the Conrad Hilton Hotel in Chicago.

•

The 6th Annual Appalachian Underground Corrosion Short Course will be held June 6-8 at the University of West Virginia, Morgantown.

•

The Shreveport Section will hold a corrosion short course February 14-15 at Centenary College, Shreveport, La.

Equipment Services NEW PRODUCTS Materials Literature

Aluminum

Resistance to corrosion attack of high temperature steam and water is claimed for a new group of aluminum alloys developed by Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh, 19, Pa. These aluminum-iron-nickel alloys have been formulated to withstand the sharply deteriorating effect of high purity water at temperatures to about 700 F.

•

Forged aluminum pipe flanges for use with aluminum butt-weld fittings are produced by Flowline Corp., New Castle, Pa. They are made in all popular sizes and are available in several types: welding neck, slip-on, lap-joint, threaded and blind.

•

An aluminum alloy that develops tensile strengths from 35 to 40,000 psi without needing heat treatment has been developed, according to Federated Metals Division of American Smelting and Refining Co., 120 Broadway, New York 5, N. Y. This enables foundries which have no heat treating facilities to produce high strength aluminum castings and to produce aluminum castings too large or too intricate for heat treatment. Called Tensaloy, the new material is an aluminum-zinc-magnesium alloy which ages at room temperatures to give mechanical properties equivalent to heat treated alloys, according to a brochure available from Federated Metals.

•

Mechanical properties superior to those of ordinary heat treated aluminum castings are claimed for Ternalloy, an aluminum-zinc-magnesium alloy described in a brochure available from Apex Smelting Company, 2537 West Taylor St., Chicago 12, Ill. Corrosion resistance, good machinability and resistance to hot cracking are other characteristics claimed by Apex.

Coatings, Application Equipment

A desk-size electrolytic process unit is designed to prepare hard-anodized samples in the lab for prototype or experimental work. The unit also can be adapted for conventional sulfuric and chromic anodizing, straight electroplating, chemical and electrochemical milling, electro-polishing, electrolytic cleaning and etching. Called the Model 500 Allen-Dizor, the unit is manufactured by Allen Aircraft Products, Inc., Ravenna, Ohio.

•

Correct atomization with lower pressures has been designed into a new airless spray gun developed by the Nordson Corporation, Amherst, Ohio. Called the Verso-Gun, it has a new internal design to increase turbulence ahead of the nozzle. Spray patterns produced can be more accurately controlled, according to the manufacturer.

Coatings, Inorganic

An inorganic zinc coating for application over weathered galvanized metal has been developed as an answer to replacing dissipated zinc on galvanized sheds, roofs, fences and equipment. The coating gives the same type galvanic protection as the original galvanizing, according to the formulator, Carboline Company, 32 Hanley Industrial Court, St. Louis 17, Mo. Called Carbo Zinc 11, the new coating has been subjected to field and lab tests.

•

A new compound for applying a chromate film to aluminum surfaces for protection against corrosion is available from the Diversey Corporation, 1820 West Roscoe St., Chicago 13, Ill. Called Divercoat 2-A, the compound can be used as a base for paint coatings or for decorative purposes. Chromate conversion coatings can be produced by immersing aluminum for a short time in a solution of 1 to 3 ounces per gallon at room temperature, according to Diversey, and do not perceptibly alter work dimensions on closely machined pieces.

Coatings, Organic

Protection of internal drill pipe surfaces from caustic effect of high alkalinity drilling fluids and from physical abuse in drilling operations is claimed for a new thermo-setting plastic coating developed by Tube-Kote, Inc., P. O. Box 20037, Houston, Texas. Under tests, the coating designated TK-34 withstood 100-degree torquing on a 10-inch pipe length and 3 percent elongation. Tube-Kote engineers state the coating has good adhesion to steel and withstands a 30-percent caustic soda solution at 200 F. It also performed well in pressures to 10,000 psi at 300 F.

•

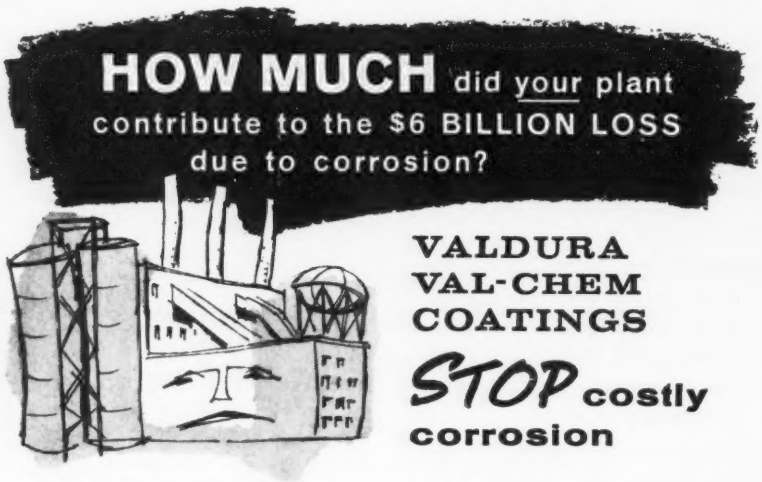
Solution to various corrosion and deterioration problems are discussed in a new bulletin (No. T-97-61) on Bitumastic cold-applied coatings available from the Koppers Company, Inc., Tar Products Division, Koppers Bldg., Pittsburgh 19, Pa.

Instruments

Accurate measurements of sea water salinity to 20 parts per million by measuring the conductivity of sea water are part of the engineering design for a salinometer being developed by Atlantic Research Corporation, Alexandria, Va. The instrument originally designed by the Pacific Naval Laboratory and the University of Washington, is being engineered by Atlantic Research for the U. S. Coast and Geodetic Survey.

•

A portable pH meter engineered in Switzerland and manufactured in the

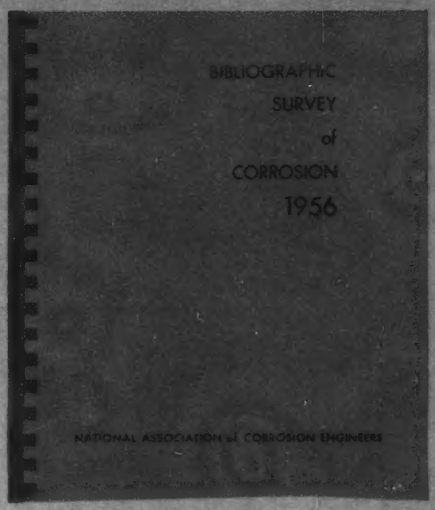


Your plant's share of the tremendous loss to corrosion last year could have been stopped with one of Valdura's Val-Chem chemically-resistant coatings. Remember—no one coating can solve all the problems. That's why Valdura offers you a *complete line* to fit every need—the new, field-tested Val-Chem Coatings. The assistance of Valdura's nationwide force of field representatives—experts in corrosion control—is at your service. How can Val-Chem Coatings stop corrosion in *your* plant? Write today on your letterhead for a prompt solution!

VALDURA HEAVY DUTY PAINT DIVISION
AMERICAN-MARIETTA CO., CHICAGO 11, ILL.

Use This Book in Solving Your Corrosion Problems

uccesses and failures of hundreds of corrosion-control workers, useful scientific and ngineering data and paths to many new ideas are available to you in the NACE ibliographic Survey of Corrosion. Save valuable time, costly materials by using he abstracts keys to a multitude of problems. Thirty-one abstracting agencies pro- ide the abstracts from hundreds of sources in this useful volume.



1956 Bibliographic Survey of Corrosion

NACE Members **$22.50**

(Non-Members, $27.50)

Contents: 2136 abstracts of articles, books, pamphlets published in 1956; complete NACE Abstract Filing Index keyed to page numbers; horoughly cross-referenced throughout; alphabetical index of 2859 authors; exhaus- ve alphabetical subject index. Plastic back, flat opening, tough book paper.

Use This Postcard to Order Your Copy of This Useful Reference Book Today!

Save Money on Earlier Issues!

Get a complete set of earlier bib- iographies, 20,045 abstracts of orrosion control literature, 1945- 5 inclusive. Postpaid, U. S. Can- da, Mexico, 6 volumes complete $40

(For addresses outside U. S., Canada and Mexico dd $1.95 for book post registry on orders for all six olumes.)

	Per Copy
1954-55 Volume containing 4287 Abstracts	
NACE Members	$15.00
Non-Members	$20.00
1952-53 Volume containing 3344 Abstracts	
NACE Members	$10.00
Non-Members	$12.50
1950-51 Volume containing 4454 Abstracts	
NACE Members	$10.00
Non-Members	$12.50
1948-49 volume containing 3512 Abstracts	
NACE Members	$10.00
Non-Members	$12.50
1946-47 volume containing 3362 Abstracts	
NACE Members	$ 7.00
Non-Members	$ 9.00
1945 volume containing 1086 Abstracts	
NACE Members	$ 4.00
Non-Members	$ 5.00

This book is not indexed by the NACE Abstract iling System.)

FOREIGN REMITTANCES should include additional 5 cents per single book for book post registry to ddresses outside the U. S., Canada and Mexico. For ll seven volumes include $2.55 for registry.

Please send me the following NACE BIBLIOGRAPHIES:

	NACE Members	Non-Members		NACE Members	Non-Members
☐ 1956	$22.50	$27.50	☐ 1948-49	$10.00	$12.50
☐ 1954-55	$15.00	$20.00	☐ 1946-47	$ 7.00	$ 9.00
☐ 1952-53	$10.00	$12.50	☐ 1945	$ 4.00	$ 5.00
☐ 1950-51	$10.00	$12.50	☐ 6 volumes 1945-55		$40

Check one: Remittance Herewith ☐; Bill me ☐

Mail to: (Please typewrite or print)

Name

No. Street or P. O. Box

City Zone State or Country

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 3027, (Sec.34.9), Houston 2, Texas

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Building

Houston 2, Texas

can you use more information in solving your corrosion problems?

Recognizing your need to keep abreast of what is going on in the rapidly expanding technology of corrosion control, NACE is examining its abstract information services with the view of making improvements. Because any improvements will be for your benefit, NACE is asking for your help in estimating the relative merits of several possible kinds of literature information services.

As an active corrosion control worker you are the best judge of what kind of information you need and how much it is worth to you. What you tell us will be helpful also in guiding NACE to improve its usefulness to industry.

Some of the abstract services NACE might offer are

1. **Print abstracts on plain index cards for sale on a subscription basis.**
2. **Print abstracts on loose-leaf sheets which can be inserted in a permanent binder.**
3. **Print abstracts in a monthly or bi-monthly bulletin.**
4. **Continue to publish abstracts on punch cards as at present.**
5. **Print abstracts in a bulletin in such a way that they can be cut out and pasted on cards.**
6. **Print abstracts in multiples on sheets of card stock so they can be cut into separate cards if desired.**
7. **Supply abstracts in annual Bibliographic Surveys only.**

Postage Will be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 3027, (Sec.34.9), Houston 2, Texas

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Building

Houston 2, Texas

Preferred NACE abstract services are checked in order of desirability: (First choice "1", etc.)

1. Plain index cards . . . . . ☐
2. Loose-leaf sheets . . . . . ☐
3. Abstract bulletin . . . . . ☐
4. Punch cards as at present . . . . . ☐
5. In bulletin for card paste-up . . . . . ☐
6. Card stock for cut outs . . . . . ☐
7. Annual book only . . . . . ☐

Name

No. Street or P. O. Box

City Zone State or Country

I would be willing to pay $150 $100 $50 $40 $30 $20 $15 $10 annually for this service.

give us your views on this post card

NACE needs to know also how much you are willing to pay for the abstract information service you favor. A place is provided in the post card ballot (left, below) for you to indicate how much you value the service you want.

It will be helpful to us if you will check in the squares provided in the form the relative merit of the various alternatives described. Mark your first choice "1"; your second, "2" and so on.

Put a circle around the amount you consider reasonable to pay for your first choice of service. Circle one amount, only.

If you are interested in more information about any of these services you may so indicate by giving us your name and mailing address. This entails no obligation. Otherwise your name is not required. We are glad to answer your questions about the NACE Abstract Punch Card Service and the NACE Bibliographic Surveys of Corrosion.

United States that features constant readings for quality control use and shock resistance is being distributed by Sel-Rex Instruments, Inc., 81 River Road, Nutley 10, N.J. Called the Electrion, the meter is designed to give accurate readings with only once-a-week standardization.

•

A pipe thermometer that clips to steam, water, refrigeration gas and other pipes has been developed by Abrax Instrument Corp., 179-15 Jamaica Ave., Jamaica 32, N.Y. Twin spiral spring clips eliminate the need for branching or drilling on pipes. Thermometers are precalibrated to counteract possible error through radiation or convection heat losses.

•

Calculation of rate of delay of radioactive isotopes can be made with a new slide rule available from Dyna-Slide Co., 600 S. Michigan Ave., Chicago 5, Ill. Five inches in diameter and made of plastic, the slide rule is used to determine the fractional amount of a radioactive isotope remaining after an elapsed period of time.

•

An elevated temperature thermocouple reference junction designed for portable in-plant or laboratory use is being distributed by Temptron, Inc., 7030 Darby Ave., Reseda, Cal. It is designed around a simple, on-off type temperature control system which operates on a small temperature differential. The unit has screw tie point terminals for direct thermo element contact to eliminate errors normally occurring from temperature gradients across the connectors.

•

A transistorized level control designed to be so sensitive that distilled or dionized water completes the 15 microamp circuit through the probes is available from Precision Thermometer & Instrument Co., 1434 Brandywine St., Philadelphia 30, Pa. The control has no moving parts contacting the liquid, no floats to clog or jam and no tubes or batteries to replace. It is designed to give differential level control with probes at different levels and has sensitiviey adjustment for liquids of various conductivity.

•

An ultrasonic flaw detector has been designed to measure thickness of metals and plastics from one side with accuracies within plus or minus 0.010 inch. It has a newly developed caliper attachment by which the operator can determine thickness directly without calculations or interpolation. Called the Sonoray, the detector is marketed by Branson Instruments, Inc., 40 Brown House Rd., Stamford, Conn.

•

Pipe detector designed for finding underground pipe has been used to locate two offshore pipelines. The detector successfully located the lines though the signal had to travel through 10 feet of mud and sand, 20 feet of water and 8 feet of air, according to Tinker and Rasor, P. O. Box 281, San Gabriel, Cal. A signal was applied to the lines on shore with an audio oscillator. A boat made a series of oblique passes over the line with an operator suspending an 8-inch inductance coil eight feet off the surface of the water. A photograph of this procedure was published on Page 26 of the December issue.

Metals, Ferrous

An illustrated technical bulletin on nitriding processes has been prepared by Armour Industrial Chemical Co., 110 N. Wacker Drive, Chicago 6, Ill. It covers the case hardening of metals with anhydrous ammonia atmospheres in various nitriding applications.

•

An ultra-high strength steel called MX-2 designed and developed by the Scaife Company, 26 Ann, Oakmont, Pa., for missile motor case uses has been made available for general industrial use. This alloy is a cobalt-modified, low-alloy, high strength construction steel that is said to have two to three times the strength of normal construction steels and yet can be readily fabricated by rolling, forming, deep drawing, welding and machining.

•

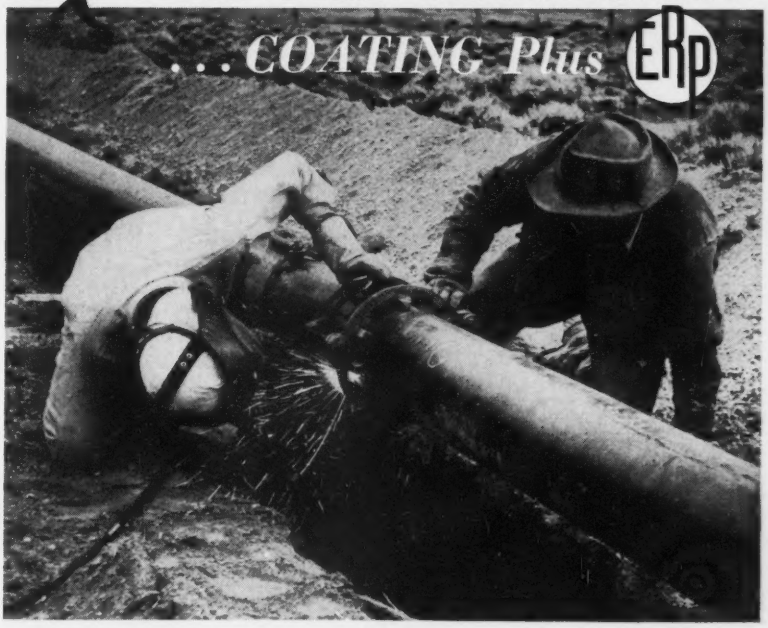
Better resistance of steel to fatigue is one improvement expected from a new vacuum degassing unit to remove oxygen during melting operations. The Dortmund-Horder unit is being used at the Midland works of the Crucible Steel Company of America, Pittsburgh 22, Pa. The unit also is expected to eliminate the long, slow cooling cycle required for some grades of steel and to increase the yields resulting from better cleanliness of the steel.

Plastics

Technical data and product information on Penton, a chlorinated polyether, are

(Continued on Page 36)

Rx FOR SURE PROTECTION



You've made a worthwhile investment in this pipe. You've spent some more on cleaning and coating. Why risk the cost of digging it up in a few years to repair corrosion damage?

With ERP protection you won't need to. Electro Rust-Proofing takes care of those pinpoints of corrosion that even the best coating cannot prevent. When your pipeline is laid, ERP makes a test survey to determine your needs. Once cathodic protection is installed, a periodic service visit by ERP engineers keeps your pipeline new—for good. They adjust your protection as your needs or environmental conditions vary.

ERP installs corrosion protection anywhere . . . at any time. But your greatest savings come if you call ERP early . . . if you plan your protection while you plan your pipeline. Write ERP today—Dept. E.55.27.

ERP CATHODIC PROTECTION SINCE 1935

ELECTRO RUST-PROOFING CORP.

A SUBSIDIARY OF WALLACE & TIERNAN INC.

30 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CABLE: ELECTRO, NEWARK, N. J.

PENTON® AT WORK...TANK LININGS

In processing systems, it's what's inside that counts

Penton linings readily convert carbon steel tanks into vessels capable of handling corrosive liquids at elevated temperatures. Thus it is now possible to get corrosion resistance *inside* chemical processing systems, where it really counts, without recourse to the high-cost materials previously required in many use areas.

Today there is a qualified tank liner in your area, experienced with Penton, and able to employ it to meet your specifications. Because Penton resists more than 300 common reagents, at temperatures far in excess of those possible with most conventional lining materials, it can offer you important savings in original cost, maintenance, and in many instances permit higher processing temperatures for increased yields.

Want more information on Penton tank linings? Write for your copies of "The ABC's of Penton for Corrosion Resistance," and "The Penton Buyer's Guide," which includes a complete listing of Penton tank liners, and producers of other types of Penton processing equipment.

CP61-1

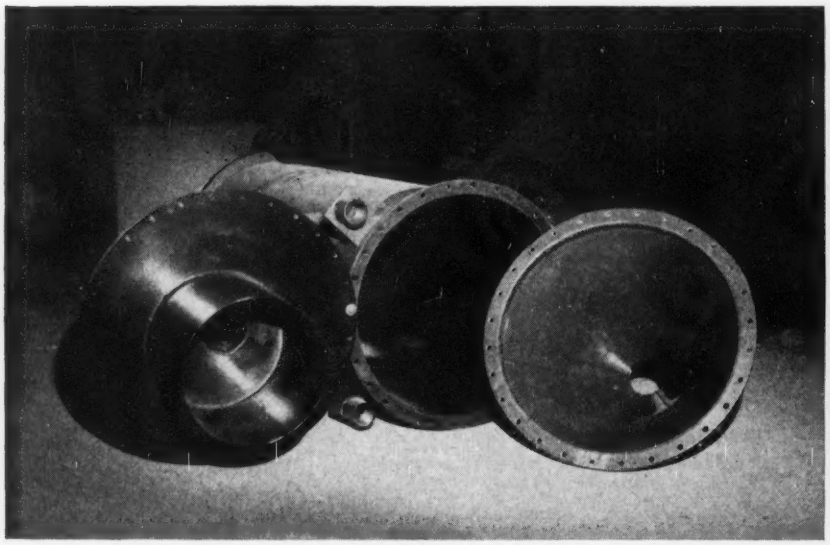
Cellulose Products Department

HERCULES POWDER COMPANY

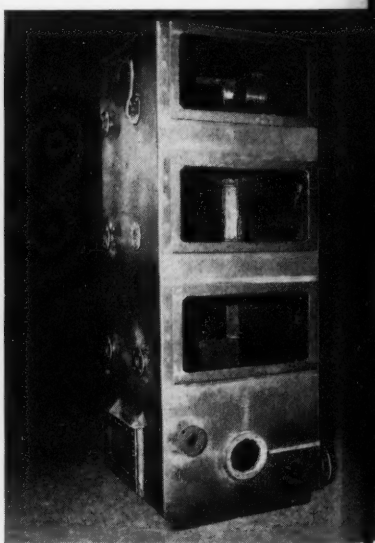
INCORPORATED

Hercules Tower, Wilmington 99, Delaware

Penton sheet used in fabricating tank linings illustrated on these pages manufactured by Garlock, Inc., Camden, N. J.

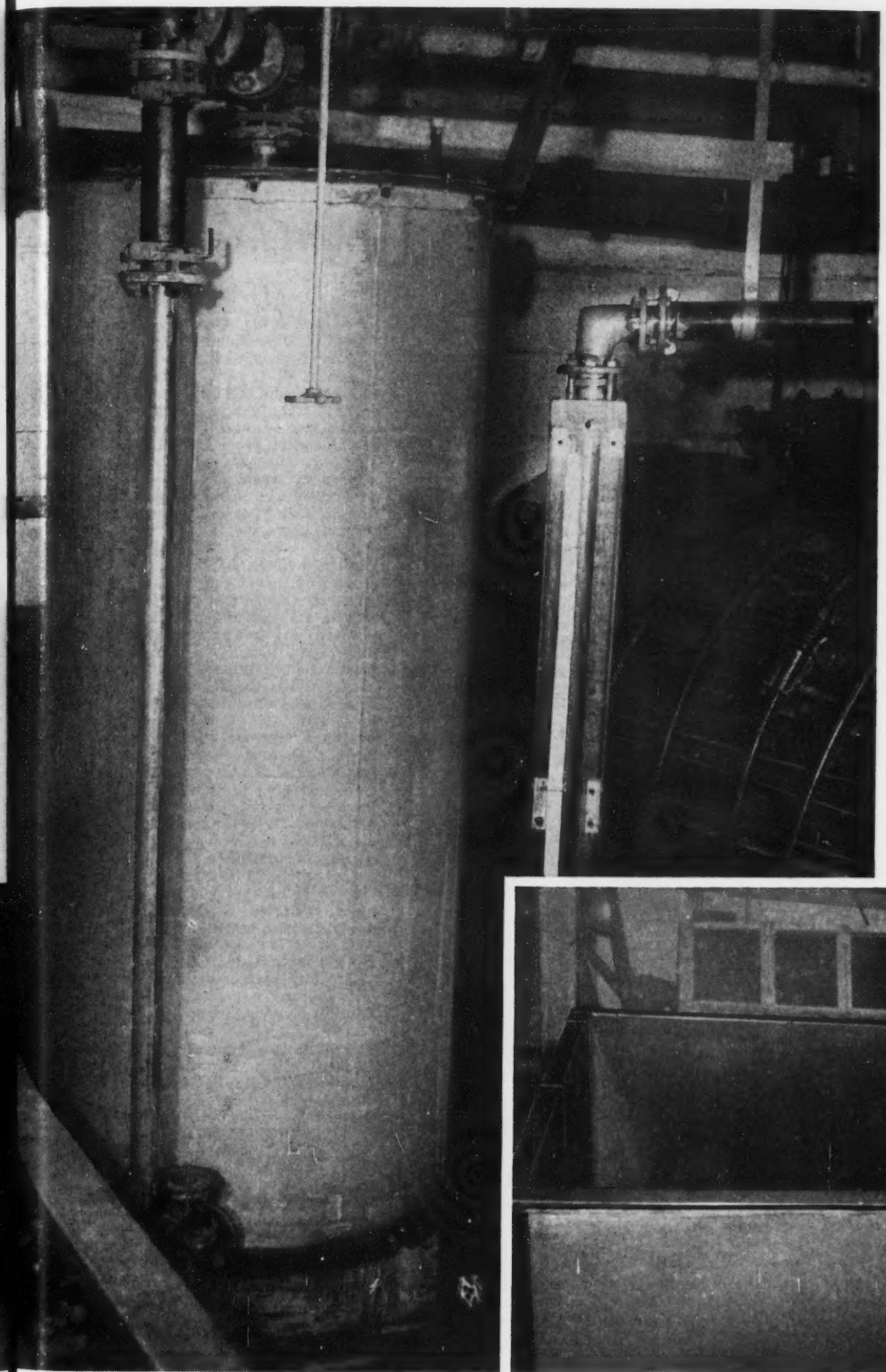


Courtesy, Electro Chemical Engineering Co., Emmaus, Penna.



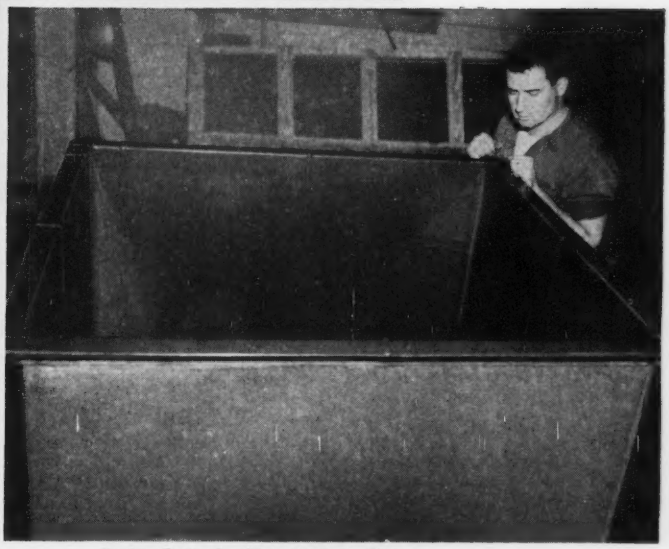
Courtesy, Mercer Rubber Corporation, Little Ferry, N. J.

TAILORED TO YOUR SPECIFIC NEEDS. The complex shapes shown here demonstrate the versatility of Penton linings applied to low-cost metal substrates for high temperature corrosion resistance. Penton-lined pipe and fittings, valves, meters and pumps can be used in conjunction with such vessels to supply a complete anticorrosion processing system based on Penton.



Courtesy, Electro Chemical Engineering Co., Emmaus, Penna.

USE IT WITH CONFIDENCE. This Penton-lined tank installed in a large East Coast chemical plant has already celebrated its first anniversary of trouble-free service. Used for off-gas condensate, it handles a mixture of 15% HCl and 69% acetic acid in water, at temperatures ranging from 170°F. to 212°F.



Courtesy, Buckley Iron Works, Dorchester, Mass.

ECONOMICALLY APPLIED. Penton linings for large tanks and processing vessels are achieved by the use of adhered sheet ranging in thickness up to 40 mils, applied to low-cost metal substrates with a straightforward adhesive system and conventional gas welding.

NEW PRODUCTS

(Continued From Page 33)

given in a new brochure available from Hercules Powder Company Wilmington, 99, Del. Included are physical, mechanical, and thermal properties chemical resistance, relative corrosion resistance values and electrical properties. The brochure also explains applications of Penton by injection molding, extrusion and for solid or lined pipe and tank linings.

•

Water softener brine tanks molded of polyethylene as a single unit are being produced in the new SinTrex Division of the Amos-Thompson Corporation, Edinburg, Ind. Measuring 19 by 38 inches and larger, the tanks are molded by the Amos SinTrex process which allows molding of large plastics products.

•

Hose couplings, nipples and adapters are being produced in a special high impact nylon in sizes from ¼ to 1 inch with either standard iron pipe or garden hose threading or in combinations of the two threadings. Marketed under the name Tuff-lite, the fittings are designed for resistance to corrosion, abrasion, contamination and heat. Additional information can be obtained from Dixon Valve & Coupling Co., 1700 N. 2nd St., Philadelphia 22, Pa.

•

An epoxy adhesive for repairing steel storage tanks called Humble-Weld 900 is produced by Humble Oil & Refining Co., Houston, Texas. It is said to be especially effective in sealing weeping type steel rivet heads and tanks seams. It also can be used for repairing tank bottoms and other areas with patch plates, according to Humble.

•

A reduction of one half in the cost of Teflon impregnated braided packing has been achieved by advanced manufacturing technology, according to Garlock Inc., 457 Main St., Palmyra, N.Y. Designated Garlock style 5875, the white asbestos braided packing is recommended for use on rotary and centrifugal shafts, valve stems and expansion joints and reciprocating rods, plungers and rams. It has corrosion resistance to minerals, acids and caustics.

•

Flintkote Company, 30 Rockefeller Plaza, New York 20, N.Y., has acquired licenses from Rand Development Corporation to use the latter's spray-up process of reinforced plastics used for production of boats, trucks, trailers, buildings, sidewalks, swimming pools and building materials. This agreement permits Flintkote to combine its Sealzit gun with Rand's spray-up process.

Testing

A new research firm has been set up to examine an engine's lubrication oil for trace amounts of wear metal to determine trouble spots in the engine before extensive damage occurs. Called Analysts, Inc., 2910 Ford St., Oakland, Cal., the commerical chemical laboratory has been designed especially for scientific control of engine maintenance for trucking, bus and shipping companies.

Stands to hold parts for use in autoclave corrosion tests have been designed for maximum temperature and humidity resistance by Wiretex Manufacturing Co., Inc., 40 Mason St., Bridgeport, Conn. Stands are made of Type 347 stainless steel and 304 low carbon stainless mounted on a one-inch thick plate. Stands of various sizes can be ordered to meet specific needs.

MEN in the NEWS

Three promotions have been made at the Pipe Coating Division of H. C. Price Co., Bartlesville, Okla. **H. Nelson VerSoy,** Gulf Division manager at Harvey, La., has been advanced to general superintendent of the Pipe Coating Division at Bartlesville, Okla. **Leo C. Carle** will succeed Mr. VerSoy. **Vernon J. Jones** has been promoted to plant superintendent at the Harvey, La., plant.

•

Walter C. Archinal has been appointed superintendent of coatings production for Metal & Thermit Corporation's plant at Carrollton, Ky.

•

Thurman E. Brown has been named director of development for Columbia-Southern Chemical Corporation's research and development laboratory at Corpus Christi, Texas. He succeeds **C. J. Sindlinger,** recently appointed planning department manager for the company's general office, 632 Fort Duguesne Blvd., Pittsburgh, Pa.

•

Myron Frank has been appointed product manager for Ambitrol products in the Chemicals Department of Dow Chemical Co., Midland, Mich.

•

Two new vice presidents have been elected to the board of directors for Hooker Chemical Corp., Box 344, Niagara Falls, N. Y. **Chris A. Stiegman** is vice president of research and development; **Charles C. Hornbostel** is vice president of finance.

•

Robert Elliott Howard has joined the Metal Physics Section of the Metallurgy Division of the National Bureau of Standards, Washington 25, D. C.

•

James N. Landis, vice president of the Bechtel Corporation, 200 Bush, San Francisco 4, Cal., has been elected president of the Engineers Joint Council. **George E. Holbrook,** vice president of E. I. du Pont de Nemours & Co., Wilmington, Del., was elected vice president of the council.

•

Robert W. Johnson has been appointed vice president of marketing and sales for Graver Tank & Mfg. Co., Division of Union Tank Car Co., 4809 Tod Ave., East Chicago, Ind.

•

Three personnel changes in the sales staff of Jones & Laughlin Steel Corporation's Stainless and Strip Division have been made. **W. M. Koenig,** 1732 Elevado Ave., Arcadia, Cal., has been appointed assistant western regional manager. **Harry E. Knuff,** 35525 Larkmoor, St. Clair Shores, Mich., has replaced Mr. Koenig as product manager of billets, bars and wire at the division office in Detroit, Mich. **T. A. Winnard,** 3203 Prairie, Royal Oak, Mich., has been named supervisor of sales and customer services at the company's Detroit plant.

CORROSION-RESISTANT

From Flange to Flange — Inside and Out!

Ductwork by du Verre

Over a wide range of corrosive and erosive conditions, du Verre Resin Bonded Fiberglass has proved its superiority over coatings, linings and other traditional "resistant" materials. Completely homogenous, du Verre fabricated ducts, fittings, hoods and tanks provide uniform protection from flange to flange, inside and out. One-quarter the weight of steel, du Verre fabrications also save you money on freight, handling and erection. Whatever your process needs, equipment can be du Verre fabricated to your specifications. Write today. Ask for Bulletin No. 101 and see how du Verre can eliminate the high cost of corrosion and product contamination.

du Verre inc.

First in Quality for Complete Corrosion Control with Reinforced Plastics

BOX 37-L • ARCADE, NEW YORK

TECHNICAL COMMITTEE ACTIVITIES

T-5C-2 Meeting Includes Papers And Study Reports

Five technical papers were presented at the Spring meeting of T-5C-2 on Corrosion by Cooling Waters (North Central Region) held in Cleveland, Ohio. About 40 members and guests attended a 1-day meeting.

Papers presented were as follows: (1) Microbiological Sampling Techniques and Their Interpretation of Microbiological Analyses by B. F. Sheema of Betz Laboratories, Inc., Philadelphia, Pa., (2) The Ryzner Index, Langelier Index and Other Tools Useful to the Water Treater by E. H. Hurst of Nalco Chemical Co., Chicago, Ill., (3) Use of Plastic Fill in Water Cooling Towers by G. W. McLaughlin of Fluor Corp., (4) Use of Magnesium Anodes in Protecting Cooler and Condenser Parts in Fresh Water Service by H. Halford of Mobil Oil Co., East St. Louis, Ill., and (5) Unusual Problems Which Confronted a Water Treatment Company Service Engineer and Their Solutions by J. M. Harvey of Charles H. Tate Co., Cleveland, Ohio.

The meeting also included reports from two study groups set at the task group's first meeting. The first report on corrosion coupons indicated that there is not much similarity in types of coupons used by industry and water treatment companies to evaluate effectiveness of corrosion control. The second report was a cooling water system questionnaire sent to north central industry to determine the types of RCW systems being used and problems encountered. There seemed to be no apparent correlation of the data. A wider distribution of a modified questionnaire has been planned.

Sixty-Eight Attend T-1C Organization Meeting

Sixty-eight members and guests attended the organization meeting of T-1C on Detection of Corrosion in Oil Field Equipment, held during the South Central Region Conference at Tulsa, Okla., October 25.

Two task groups were established at the meeting. Harry J. Kipps of Signal Oil and Gas Co., Long Beach, Cal., was appointed chairman of one task group to work on detecting external casing corrosion by logging means.

L. K. Gatzke of Shell Oil Co., Denver, Colo., was appointed chairman of another task group on use of corrosion probes, primarily the resistance type.

Discussions at the meeting included chemical methods of corrosion detection, use of iron counts as a measure of corrosion in producing wells and methods for detecting oxygen.

•

The 7th Annual Houston Section Corrosion Control Short Course will be held February 2-3 at the Rice Hotel, Houston.

Committee T-1H Sets Up Five Geographic Area Task Groups

Fifty-seven members and guests attended the first meeting of Unit Committee T-1H (Economics of Corrosion Control) held since the re-organization of Group Committee T-1 (Corrosion in Oil and Gas Well Equipment). The meeting was held October 26 during the South Central Region Conference in Tulsa, Okla.

Scope and purpose of the unit committee were discussed and task groups set up. Committee T-1H will consider all corrosion problems in oil and gas production operations to determine corrosion control economics in all phases of production. Purpose of the committee will be to enable corrosion engineers to show the advantages of corrosion control to all levels of management and to assist these engineers in selecting the most economical methods of corrosion control.

Because of the wide range of corrosion problems encountered in different producing areas of the country, the committee has been divided into five task groups: T-1H-1 West Coast Area, T-1H-2 Gulf Coast Area, T-1H-3 Permian Basin Area, T-1H-4 Rocky Mountain Area and T-1H-5 Midcontinent Area. At the present time, the Midcontinent Area will include the East Texas Field.

Chairman for each of the task groups was selected as follows: T-1H-1, H. J. Kipps of Signal Oil & Gas, Long Beach, Cal., T-1H-2, W. F. Oxford of Sun Oil Co., Beaumont, Texas, T-1H-3 Fair Colvin, Jr., Atlantic Refining Co., Midland, Texas, T-1H-4 Howard W. Olson of Shell Oil Co., Denver, Colo., and T-1H-5, Harry G. Byars of Atlantic Refining Co., Dallas, Texas.

J. P. Stanton gave a presentation on the use of statistical analysis to detect major variables influencing oil field corrosion rates and inhibitor performance.

Inhibitors, Test Specimens Discussed at T-5E Meeting

Use of inhibitors to prevent stress corrosion cracking, standardization of test specimens and use of coatings under insulation to prevent stress cracking were discussed at the October meeting of Technical Unit Committee T-5E (Stress Corrosion Cracking of Austenitic Stainless Steel) held during the Northeast Region Conference at Huntington, W. Va.

Recognition was given during the meeting to persons who gave major assistance in developing material for the ASTM report on stress corrosion cracking recently published.

T-6D Expands Its Scope With 4 New Task Groups

Four new task groups were set up to expand the scope of work by Unit Committee T-6D at its meeting held October 25 during the South Central Region Conference in Tulsa, Okla. Sixty guests and members attended the meeting.

The task groups formed and their chairmen are as follows: T-6D-7 on Industrial Maintenance Painting Problems, C. R. Martinson; T-6D-8 on Contract vs Paint Maintenance Painting, Charles E. Fox; T-6D-9 on Engineering Design for Corrosion, J. L. Weis; and T-6D-10 on Training Films, E. W. Oakes.

Jim Bennett gave a presentation on abrasives, explaining why and where different blasting media are used.

•

News deadline for CORROSION is the 10th of each month.

Membership in NACE Technical Unit Committees

A question frequently asked by guests attending meetings of Technical Unit Committees is "How may I become a member of this committee?" This question is answered in the following procedure quoted from the Technical Committee Operation Manual:

1. Any member of NACE (irrespective of place or country of residence) may become a member of a Technical Unit Committee upon fulfillment of the following requirements.

2. He should apply in writing to the Chairman of the Unit in which he desires membership, stating his interest and willingness to participate in the activities of the Unit and giving his experience in the subject.

3. Approval by the Chairman of the Unit Committee of the application or by majority vote of committee members by letter ballot is necessary for appointment of an applicant to membership in a Unit Committee.

4. The Chairman of the Unit Committee will notify each applicant of his acceptance or rejection.

A directory of NACE Technical Unit Committees and Officers is published in the January, April, July and October issue of CORROSION.

Task Groups Formed By T-6B to Study Plated Coatings

Two new task groups were formed at the October meeting of Technical Unit Committee T-6B on Protective Coatings for Resistance to Atmospheric Corrosion. Sixty members and guests attended the meeting.

Task Group T-6B-19 was formed to work on galvanizing. Ray Vickers was appointed chairman; J. A. Heath, Jr., vice chairman.

Task Group T-6B-20 also was formed to study metallizing. Chairman is to be appointed later.

Chuck B. Wills of E. L. Lester & Co., Houston, Texas, showed a film and discussed water blasting as a means of surface preparation. J. F. Vander Henst, NACE Technical Secretary, gave a talk on NACE technical committee structure and operation. He outlined the various rules and regulations controlling a unit committee and the other NACE committees.

Task Group T-6B-2 on Ester Gum Oil was cancelled.

A discussion was held on galvanizing. Talks have been obtained on galvanizing and polyurethane foam for the March meeting to be held at Buffalo during the 17th Annual NACE Conference.

Forty Members and Guests Attend T-2D Tulsa Meeting

Forty members and guests attended the T-2D (Methods for Measuring Pipe Coating Leakage Conductance) committee meeting held October 26 at the South Central Region Conference in Tulsa, Okla.

Discussions included one member's explanation of his technique for measuring coating leakage conductance. Pipe-to-soil potential is plotted on straight coordinate paper, then the area under the curve is measured with a planimeter and divided by the base dimension to obtain an average value of change in pipe-to-soil potential.

A test method was proposed by another member in which all readings would be made with the energizing source in a steady on condition rather than interrupting the energizing source. To obtain a change in potential measurement, another set of measurements would be made with the energizing source set at a different current output.

Fifty-two NACE technical practices committee meetings are scheduled for the Buffalo Conference, March 13-17. See Page 46 for a list of these committees and a time schedule.

CORROSION ENGINEERING DIRECTORY

WAYNE BROYLES ENGINEERING CORP.
CATHODIC PROTECTION
Installation
DESIGN SURVEYS
P.O. Box 1169 • FAirfax 3-6858 • Houston 1, Texas

Electro Rust-Proofing Corp.
Engineering Division
ERP
Corrosion Surveys
Cathodic Protection Design
Plans • Specifications
Electrolysis Control
Testing
BELLEVILLE 9, NEW JERSEY
Atlanta • Chicago • Dallas • Monrovia

FRANCIS W. RINGER ASSOCIATES
• *Consulting Corrosion Engineers*
7 Hampden Ave. MOhawk 4-2863
NARBERTH (Suburb Phila.) PENN.

cathodic protection service
CPS
Twenty cathodic protection engineers with a combined total of over 150 years experience available to serve you with ABILITY and INTEGRITY.
Houston 4601 Stanford St.
Branch Offices: Chicago • Corpus Christi
New Orleans • Odessa • Tulsa

CATHODIC PROTECTION
• ENGINEERING
• SURVEYS • CONSTRUCTION
Systems for conventional and specialized applications
THE HARCO CORPORATION
4592 East 71st St. VUlcan 3-8787
Cleveland 25, Ohio

A. V. SMITH ENGINEERING CO.
CONSULTING ENGINEERS
Essex Bldg. Narberth, Pa.
119 Ann Street Hartford 3, Conn.

CATHODIC PROTECTION by Coreco
SURVEYS • DESIGNS
INSTALLATIONS
CORROSION RECTIFYING CO., INC.
5310 ASHBROOK • MO 7-6659
HOUSTON 36, TEXAS

THE HINCHMAN CORPORATION
Consulting Engineers
"WORLD-WIDE ACTIVITIES"
Survey • Design • Supervision
Specializing In
Corrosion Control • F.C.C. Certification Tests
Electromagnetic Interference Studies
Francis Palms Bldg. Detroit, Mich.

SOUTH FLORIDA TEST SERVICE
INCORPORATED
Testing—Inspection—Research—Engineers
Consultants and specialists in corrosion, weathering and sunlight testing.
4301 N.W. 7th St. • Miami 44, Florida

CORROSION SERVICE LIMITED SL offers in CANADA
A Complete Service in Corrosion Engineering
Design and installation of cathodic protection systems. Supervision. Resistivity and electrolysis surveys. Selection and application of protective coatings.
17 DUNDONALD ST., TORONTO 5

ICCC Interprovincial Corrosion Control Company Limited
5325 Third St. S.E. Calgary, Alberta
CANADA
P. O. Box 310 Burlington, Ont.
CONSULTING ENGINEERS
Survey Design — Materials and Equipment — Installations

WATER SERVICE LABORATORIES, INC.
CORROSION PREVENTION
Specialists in Water Treatment
Main Office, 615 West 131st St., N. Y. 27, N. Y.
Offices Also in Philadelphia, Washington and Richmond, Va.

CORROSION ENGINEERING
EBASCO SERVICES
INCORPORATED
TWO RECTOR STREET, NEW YORK 6, N. Y.
CHICAGO • DALLAS • PORTLAND, ORE.
SAN FRANCISCO • WASHINGTON, D. C.

"PUTTING PERMANENCE IN PIPE"
For Over 30 Years
MAYES BROTHERS, INC.
1150 McCarty Phone: OR 2-7566
HOUSTON, TEXAS

Reach more than 8000 paid readers monthly in this directory at a cost of about $1.50 per thousand. Ask for rates.

Final Program Given For Houston Section's Feb. 2-3 Short Course

Final program arrangements have been made and are given below for the 7th Annual Houston Section Corrosion Control Short Course to be held February 2-3 at the Rice Hotel, Houston.

The first day will be devoted to lectures on fundamentals and general principles of corrosion control systems; the second day's sessions will be divided into five areas: pipe line system, oil and gas production, refineries and industrial plants, utilities and commercial and residential design. A schedule of the second day activities is given below in the table.

NACE Treasurer C. G. Gribble, Jr., of Metal Goods Corp., will give the opening address entitled "Six Billion Dollars Is Too Much!"

Other speakers and their subjects for the first day's sessions on fundamentals and general principles are as follows:

Fundamentals of Corrosion and Corrosion Control, by M. A. Riordan of Rio Engineering Company.

Paint Systems and Internal Coatings, by H. E. Waldrip of Gulf Oil Corporation.

External Coatings for Underground Corrosion, by E. R. Allen of Humble Pipe Line Company.

Fundamentals of Inhibitors, by A. L. Mortimer of Magna Chemicals Inc., Odessa, Texas.

Fundamentals of Cathodic Protection, by Wayne Johnson of Corrosion Rectifying Company.

The three motion picture films on corrosion produced by International Nickel Company also will be shown as part of the first day's sessions on fundamentals and general principles.

South Central Region

Tulsa Section heard R. S. Ladley of Phillips Petroleum Company speak on cement lined pipe in petroleum production operations at the November 28 meeting.

•

North Texas Section had Harold Snyder of Tuboscope Company speak on non-destructive testing of metals for the December 12 meeting.

•

Alamo Section heard some of its members give informal reports on the South Central Region Conference in Tulsa for the December 15 meeting. Also included was a roundtable discussion on corrosion problems.

•

East Texas Section had H. G. Byars of Atlantic Refining Company speak on corrosion from reservoir to pipeline for its November 22 meeting.

Hanson Elected Chairman For New Orleans Section

New officers elected for 1961 by the New Orleans Section will be headed by Section Chairman Harry R. Hanson of Humble Oil & Refining Company. Other officers elected are Vice Chairman Jimmie R. Mayes of Shell Oil, Secretary-Treasurer J. W. Loewald of Coating Specialists.

R. M. Ives, Jr., of Humble Oil & Refining Co., Houston, spoke on the technology of inorganic zinc coatings at the November 28 meeting held by the New Orleans Section.

(Continued on Page 41)

SECOND DAY — FEBRUARY 3, 1961 — FIELD PROBLEMS AND FIELD PRACTICES

	8:00 - 9:20 A.M.	9:30 - 10:15 A.M.	10:30 - 11:15 A.M.
I. PIPE LINE SYSTEMS (Oil, Gas, Products) M. E. FRANK, Chairman Tennessee Gas Pipeline Co.	I a. DEMONSTRATIONS: CATHODIC PROTECTION PRINCIPLES, C. L. Woody, United Gas Corp. CATHODIC PROTECTION SYSTEMS, M. E. Frank, Tennessee Gas Pipeline Co.	I b. EXTERNAL COATINGS FOR UNDERGROUND SERVICE, E. Rudge Allen, Humble Pipe Line Company	I c. INTERNAL COATINGS, W. H. Jamison, Tennessee Gas Pipeline Co. INHIBITORS AND THEIR ECONOMICS, E. R. Allen, Humble Pipe Line Company
II. OIL AND GAS PRODUCTION (Wells, Flow Lines, Tank Interiors, Heater Treaters) J. T. PAYTON, Chairman Texaco, Inc.	II a. DEMONSTRATIONS: (Same as I a.)	II b. CORROSION PROBLEMS, DETECTION AND CONTROL PRACTICES IN PRODUCING OPERATIONS, Kelly H. Roach, Superior Oil Co., Lafayette, La.	II c. CORROSION INHIBITORS, FIELD APPLICATION, EVALUATION, AND LABORATORY TESTING, Eben D. Junkin, Jr., Tidewater Oil Co.
III. REFINERIES, CHEMICAL, PETRO-CHEMICAL, INDUSTRIAL PLANTS E. C. WINEGARTNER, Chairman Humble Oil & Refining Company	III a. DEMONSTRATIONS: ((Same as I a.)	III b. APPLICATION, OPERATION, AND MAINTENANCE OF CATHODIC PROTECTION IN REFINERIES AND PLANTS, Roy V. Comeaux, Humble Oil & Refining Company.	III c. METALS AND ALLOYS FOR CORROSION SERVICE AND HIGH TEMPERATURE SERVICE, H. M. Randall, International Nickel Co.
IV. UTILITIES: GAS AND WATER DISTRIBUTION, TELEPHONE AND POWER SYSTEMS C. L. WOODY, Chairman United Gas Corp.	IV a. DEMONSTRATIONS: (Same as I a.)	IV b. EXTERNAL COATINGS FOR UNDERGROUND SERVICE (Same as I b.)	IV c. DESIGN AND INSTALLATION OF CATHODIC PROTECTION ON CABLES, C. L. Mercer, Southwestern Bell Telephone Company
V. COMMERCIAL AND RESIDENTIAL DESIGN— HEATING AND AIR CONDITIONING M. A. RIORDAN, Chairman Rio Engineering Co.	V a. DEMONSTRATIONS: (Same as I a.)	V b. EXTERNAL COATINGS FOR UNDERGROUND SERVICE (Same as I b.)	V c. DESIGN AND INSTALLATION OF CATHODIC PROTECTION ON CABLES (Same as IV c.)

	11:25 A.M. - 12:10 P.M.	1:30 - 2:20 P.M.	2:30 - 3:10 P.M.	3:25 - 4:30 P.M.
I	I d. DESIGNING FOR CORROSION CONTROL, Tad Pazdral, Consulting Engineer	I e. DESIGN, OPERATION, AND MAINTENANCE OF CATHODIC PROTECTION SYSTEMS — CATHODIC PROTECTION INTERFERENCE, Lewis Unger, Transcontinental Gas Pipeline Corp.	I f. FIELD INSTRUMENTS, FIELD REPORTS, AND RECORDS, B. J. Whitley, Jr., Tennessee Gas Pipeline Co.	I g. ROUND TABLE DISCUSSION
II	II d. PROTECTIVE COATINGS (ATMOSPHERIC, UNDERGROUND AND MARINE) AND PLASTIC COATED TUBING, Alan S. Ahmad, Sun Oil Co., Beaumont, Texas	II e. CATHODIC PROTECTION IN PRODUCTION OPERATIONS, G. R. Roberson, Standard Oil Co. of Texas	II f. METALLURGY IN PRODUCTION OPERATIONS, M. E. Holmberg, Consultant	II g. ROUND TABLE DISCUSSION
III	III d. INTERNAL AND EXTERNAL PROTECTIVE COATINGS FOR PLANT SERVICE, F. P. Helms, Union Carbide Chemicals Co.	III e. INHIBITORS AND CHEMICAL TREATMENT FOR CORROSION CONTROL, J. M. Brooke, Phillips Petroleum Co.	III f. CORROSION DETECTION, TESTING, RECORDS, AND FIELD REPORTS, E. L. Haile, Monsanto Chemical Co.	III g. ROUND TABLE DSCUSSON
IV	IV d. DESIGN AND MAINTENANCE FOR CORROSION CONTROL IN DISTRIBUTION SYSTEMS Dan Garza, Southern Union Gas Co., Austin, Texas	IV e. FIELD INSTRUMENTS AND HOW TO USE THEM: 1. UNDERGROUND PIPE, G. T. Pike, Houston Natural Gas Corp. 2. UNDERGROUND CABLES, D. E. Simmons, Houston Lighting & Power Co.	IV f. RECORDS AND FIELD REPORTS, AND CORROSION COORDINATING COMMITTEES, T. M. Heitman, United Gas Corp.	IV g. ROUND TABLE DISCUSSION
V	V d. DESIGN AND MAINTENANCE FOR CORROSION CONTROL IN DISTRIBUTION SYSTEMS. (Same as IV d.)	V e. INHIBITORS AND CHEMICAL TREATMENT FOR CORROSION CONTROL (Same as III e.)	V f. RECORDS AND FIELD REPORTS, AND CORROSION COORDINATING COMMITTEES (Same as IV f.)	V g. ROUND TABLE DISCUSSION

Letters to the Editor

South Orange, N.J.

To Editor of CORROSION:

Congratulations to the Louisville Electrolysis Committee on their 36th birthday. Work of this committee through the years is proof of the success and value of cooperative efforts in the field of corrosion mitigation.

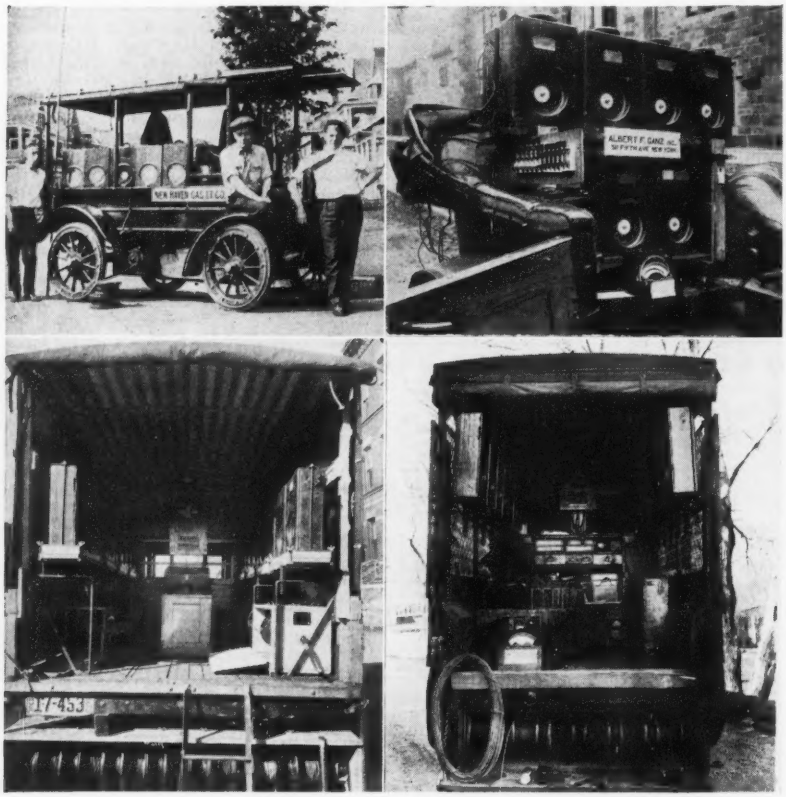
On Page 60 of the August, 1960, issue of CORROSION, the writer was surprised and pleased to recognize the picture of the electrolysis truck which had been used in 1926 in making some of the first electrolysis surveys in Louisville.

The truck was furnished by the Louisville Water Company, and the equipment was supplied and installed by our company (Albert F. Ganz, Inc., 5 Vose Ave., South Orange, N.J.). The writer was the resident field engineer in charge of the conduct of the tests and surveys under the general supervision of the Technical Committee. Six of the utility companies operating in Louisville assigned representatives to man the truck and cooperate in making the city-wide surveys.

It may be of interest to your readers to see pictures of some of the predecessors of this electrolysis testing truck. We enclose photographs of four such trucks.

We wish to compliment the electrolysis and corrosion committees throughout the country and attest to the effectiveness of their cooperative efforts and to stress the importance of the use of proper equipment and cooperation in all fields of corrosion mitigation.

Yours very truly,
D. W. Barron



Top left: Electric truck used in New Haven, Conn., around 1913, by a group of public utilities which formed the nucleus of the New Haven Electroylsis Committee. The late Charles F. Meyerherm, one of the early members of NACE, is shown seated on the truck's front fender. Top right: Recording instruments were mounted in the rear seat of a Hudson touring car by the late Albert F. Ganz and Mr. Meyerherm to conduct potential difference surveys. This photograph was taken in New Haven, Conn., in 1920. Bottom left: Rear view of large Reo Speedwagon, one of two trucks equipped for potential surveys made throughout Chicago, Ill., in 1922. Bottom right: Another Reo Speedwagon equipped with survey equipment after the 1922 Chicago survey. This truck was used by the Albert F. Ganz Company from 1923 to 1940 to make cooperative surveys in Cleveland, Ohio, Buffalo, N.Y., New Haven, Conn., northern New Jersey and New York City.

LOOK at the automobile corrosion features in the February issue of *CORROSION*.

CHEMICAL INDUSTRY FOCUS

Technical Topics to be published in the March issue will be focused on corrosion control problems in the chemical industry. Topics will cover problems in various pieces of process equipment and proper use of design and materials to control corrosion.

SECTION CALENDAR

January

9 Kansas City Section.
9 Greater St. Louis Section.
9 Central Oklahoma Section.
9 North Texas Section. Torch Restaurant, Dallas, 6:30 pm.
10 San Francisco Bay Area Section.
10 Houston Section.
10 Permian Basin Section.
10 Twin Cities Section.
10 Montreal Section.
17 Cleveland Section.
17 Chicago Section. Engineering Cathodic Protection Systems for Communication Cables, by T. J. Maitland.
18 Greater Baton Rouge Section.
19 Vancouver Section.
19 Alamo Section.
23 Los Angeles Section.
23 Tulsa Section.
31 Panhandle Section.
31 Southwestern Ohio Section. Cathodic Protection Panel, Dayton, Ohio.

February

1 Schenectady-Albany-Troy Section. "What I'd Like to Know About Corrosion," by D. A. Vermilyea, General Electric Research.
7 Philadelphia Section.
10 Rocky Mountain Section
13 Kansas City Section.
13 Greater St. Louis Section. Corrosion Resistance Properties and Uses of 17-4 PH Steel, by J. J. Halbig.
13 Central Oklahoma Section.
13 North Texas Section. Torch Restaurant, Dallas
14 San Francisco Bay Area Section.
14 Houston Section.
14 Permian Basin Section.
14 Twin City Section.
14 Montreal Section.
16 Alamo Section.
16 Vancouver Section.
21 Chicago Section. Past Chairmen's night.
21 Greater Boston Section. Biological Influences on Deterioration of Materials in Marine Environments, by Albert P. Richards.
21 Baltimore-Washington Section. Corrosion Problems in Water Handling, by D. W. Auld.
21 Cleveland Section.
27 Tulsa Section.
28 Panhandle Section.
28 Southwestern Ohio Section.

•

Sale of books in the United States totaled $630 million in 1959.

NATIONAL and REGIONAL MEETINGS and SHORT COURSES

1961
March 12—NACE Board of Director's Meeting, Hotel Statler, Buffalo, N. Y.
March 13-17—17th Annual Conference and 1961 Corrosion Show, Buffalo, N. Y., Hotel Statler.
March 17—NACE Board of Director's Meeting, Hotel Statler, Buffalo, N. Y.
Oct. 4-6—Western Region Conference, Hotel Multnomah, Portland, Oregon.
Oct. 9-11—North Central Region Conference, St. Louis, Chase Park Plaza Hotel.
Oct. 24-27—South Central Region Conference and Exhibition, Shamrock-Hilton Hotel, Houston.
Oct. 30-Nov. 2—Northeast Region Conference, New York City, Hotel Statler.
Southeast Region Conference, Miami, Fla., in conjunction with Miami Section's short course.

1962
March 19-23—18th Annual Conference and 1962 Corrosion Show. Kansas City, Municipal Auditorium.
October 1-4—Northeast Region Conference, Hotel Sheraton Ten Eyck, Albany, N. Y.
October 9-11—North Central Region Conference.
October 11-12—Southeast Region Conference, Birmingham, Ala.
October 16-19—South Central Region Conference and Exhibition, Granada Hotel, San Antonio.

1963
March 18-22—19th Annual Conference and 1963 Corrosion Show. Convention Hall, Atlantic City, N. J.
October 14-17—South Central Region Conference, Oklahoma City, Okla.

SHORT COURSES

1961
February 2-3—7th Annual Houston Section Corrosion Control Short Course, Rice Hotel, Houston, Texas.
February 14-15—Shreveport Section Corrosion Short Course, Centenary College, Shreveport, La.
June 6-8—6th Annual Appalachian Underground Corrosion Short Course, University of West Virginia, Morgantown.
June 20-21—Greater Boston Section Corrosion Short Course, Wentworth Institute, Boston, Mass.
October 14-17—South Central Region Conference, Oklahoma City, Okla.

South Central Region

(Continued From Page 39)

Shreveport Section Plans 1961 Program Subjects

Technical program topics for its regular monthly meetings throughout 1961 have been planned by the Shreveport Section. For January, the topic will be economics of cathodic protection.

Other topics for the year are as follows: February—short course; March—production equipment; April—pipe line coatings; May—plant equipment; June—annual barbecue; September—production equipment; October—cathodic protection; November—plant equipment and December—ladies night.

New Teche Section Officers To Be Installed This Month

Officers recently elected by the Teche Section are as follows: Chairman John R. Smith of Tretolite Company, Vice Chairman James R. Richards of Tidewater Oil Co., Treasurer David S. Stear of Texaco Inc., Secretary Jack A. Donnelly of Plastic Applicators and Trustee Samuel E. Fairchild of Texas Pipeline Co.

These officers will be installed at the section's annual dance to be held in January.

•

The 1961 South Central Region Conference and Exhibition will be October 24-27, Shamrock-Hilton Hotel, Houston, Texas.

March, September Issues Needed For Libraries

Persons who have surplus copies of the March and/or September 1959 issues of CORROSION are asked to mail them in to CORROSION, 1061 M & M Bldg., Houston 2, Texas, so orders for library files can be filled.

The association frequently receives orders for complete back issue files and would like to be able to fill those received from libraries.

DEATHS

Lyle R. Sheppard, a charter member of NACE and senior engineer in corrosion research at Shell Pipe Line Corporation's laboratories in Houston, Texas, died December 12 from a heart attack.

One of the early practitioners of cathodic protection and coatings for underground pipelines, Mr. Sheppard studied engineering at Carnegie Institute of Technology and received a BS and MS from the University of Houston.

He was active in NACE technical committee work and lectured at several short courses on corrosion control. He had been in pipeline corrosion control work since 1932.

Sheppard

Mr. Sheppard began his experimental work on cathodic protection with Interstate Gas Company and had been with Shell Pipeline's research laboratories for the past 15 years.

•

R. D. McCarthy, sales manager for the F. W. Gartner Company, Houston, Texas, died December 4 of a heart attack. A member of NACE since 1955, he was active in the Houston Section.

Career opportunities in corrosion research

* * *

Are you qualified for the opportunities that INCO's Laboratory offers to three additional scientists who are able to plan and conduct programs in corrosion research?

Requirements: Ph.D. or Sc.D. Also M.S. degree with research experience is acceptable.

More information is given in the current report of INCO activities, "Metals Plus Research." Do you want to review a copy?

Director of Research
The International Nickel Company, Inc.
67 Wall Street, New York 5, N. Y.

Canadian Region

Titles of Papers and Speakers Given For Western Division Conference

Western Division Conference of the Canadian Region will be held February 1-3 at the MacDonald Hotel, Edmonton, Alberta. Registration will begin the evening of January 31 at the hotel.

Included in the technical program are the following speakers and titles of their papers:

Corrosion Theory and Glossary of Corrosion Terms by J. G. Parr, University of Alberta.

Management's Views of Corrosion Control, by H. Harries, University of Alberta.

Corrosion Prediction, by Hugh P. Hodard, Aluminium Laboratories, Kingston, Ontario.

Corrosion Detection, by Harry G. Bennett, British American Oil Co., Toronto, Ontario.

Environmental Treatment, by F. W. Hewes, Caproco Corrosion Prevention, Ltd., Edmonton, Alberta.

Structural Design, by M. W. Clark, Caproco Corrosion Prevention, Ltd., Edmonton, Alberta.

Protective Coatings, by K. E. Tator, Tator Associates, Coraopolis, Pa.

Pipeline Coatings, by N. K. Senatoroff, Pacific Lighting Gas Supply Co., Los Angeles, Cal.

Cathodic Protection, by M. E. Parker, corrosion consultant, Houston, Texas.

Other conference activities include tours of industrial and chemical plants, a banquet and a special ladies program.

Conference Committee Chairmen

General chairman of the conference is F. W. Hewes of Caproco Corrosion Prevention, Ltd., Edmonton, Alberta. Other committee chairmen are given below.

Technical program, William H. Seager of Interprovincial Pipe Line Co., Ltd., Edmonton; Exhibits, Fred Pasemco of Canadian Protective Coating Ltd., Edmonton; Publicity, Harvey J. Gordon of Crose-Perrault Canada Ltd., Edmonton; Program, Russell G. Powell of Imperial Oil Ltd., Edmonton; Publication, Malcolm W. Clarke of Canadian Protective Coating, Ltd., Edmonton; Registration, Harry Lineker of Texaco Exploration Ltd., Edmonton, and Finance, John L. Gattenmeyer of Canadian Protective Coating Ltd., Edmonton.

•

Toronto Section held a joint meeting with the Electro-Chemical Society November 1. The International Nickel Company films on corrosion were shown by R. J. Law and Norman Hollefriend spoke on the fuel cells.

•

Hamilton-Niagara Section had 31 members and guests for its special "Stump the Experts" panel meeting held November 30. Five panel members discussed questions and topics of interest to the members attending.

We Make Them to YOUR Specifications

SPECIAL TEST SPECIMENS

- Any size
- Any dimensions
- Any material

We can relieve you of the trouble (and save you money) in producing special test specimens to non-standard sizes, shapes and dimensions. Our long experience and complete stock make it possible for us to serve you quickly and well.

Write, telegraph or telephone us

CORROSION Test Supplies Co.

P.O. Box 176, Baker, La.
Phone BATON ROUGE — WE 3-1315

WE SHIP ANYWHERE IN THE WORLD

Northeast Region

Pittsburgh Section had a record breaking attendance of 34 members and 24 guests at its December 1 meeting which featured a roundtable on underground corrosion. Moderator of the panel was C. A. Erickson of Peoples Natural Gas Company. Panel members included A. L. Ayres, S. C. Jones, R. M. Keller and L. H. West.

The section held a coatings roundtable for its November 3 meeting. Panel members were Alfred Artzberger, Wallace Cathcart and R. Eugene Paine.

•

Kanawha Valley Section has scheduled M. E. Carlisle of Aluminum Company of America to speak on aluminum for pipelines at the January 19 meeting. Warren Immel of Tennessee Gas Transmission also will speak on cathodic protection in plant yards.

•

Baltimore-Washington Section officers elected for 1961 are Chairman H. F. Lewis, Vice Chairman N. B. Garlock and Secretary-Treasurer T. E. Krehnbrink.

•

Philadelphia Section heard Norbert D. Greene of Rensselaer Polytechnic Institute speak on metallic passivity at the December 20 meeting.

•

Wilmington Section has scheduled R. C. Canapary of Nalco Chemical Company to speak on corrosion inhibitors for the January 25 meeting.

Section officers recently elected are Chairman K. L. Moore, Vice Chairman J. B. Arots and Secretary-Treasurer J. F. Axsom.

•

Lehigh Valley Section had R. W. Steinmetz of Western Electric speak on plant corrosion problems at the November 21 meeting held in Allentown, Pa.

•

Southern New England Section had D. Burke of Tube Turns Plastics speak on plastic pipe applications at the December 7 meeting.

•

The 1961 Northeast Region Conference will be Oct. 20-Nov. 2 at the Hotel Statler, New York City.

North Central Region

Twin City Section had W. Z. Friend of International Nickel Company speak on stainless steels and their corrosion resistance characteristics at the December 13 meeting.

•

Kansas City Section heard John E. Wright of the Gas Service Company speak on the infrared method of leak detection at the November 14 meeting.

•

Chicago Section elected its 1961 officers at the November 15 meeting. They are Chairman Wayne H. Schultz of Dearborn Chemical Co., Vice Chairman David B. Sheldahl of Sinclair Research Laboratories, Inc., Secretary L. LeRoy Swan of Illinois Bell Telephone Co., and Treasurer Richard Rue of Insulmastic, Inc.

Guest speaker at the meeting was H. D. Segool of the Kendall Company who spoke on pressure sensitive tapes.

•

Southwestern Ohio Section had W. E. Kemp of Koppers Company, Inc., speak on underground and industrial coatings for the November 29 meeting.

•

The 1961 North Central Region Conference will be October 9-11, Chase Park Plaza Hotel, St. Louis, Missouri.

Southeast Region

Ohio Valley Section officers recently elected for 1961 are as follows: Chairman C. Norman Beck of Louisville Gas & Electric Co., Vice Chairman John S. Heintzman of Southern Bell Telephone Co., and Secretary-Treasurer Robert L. Whitehouse of Irwin H. Whitehouse & Sons.

•

Birmingham Section officers for 1961 were elected at the November 4 meeting. They are Chairman Marion M. Fink of Tennessee Coal & Iron, Fairfield, Ala., Vice Chairman James C. Ray of Southern Bell Telephone Co., Secretary-Treasurer Douglas D. Holmes of Alabama Power Co., and Assistant Secretary-Treasurer Mrs. Byrtle M. Bourziel of Wholesale Coke Company.

Western Region

Portland Section Officers Headed by George K. Merz

The Portland Section recently elected its officers for 1961. They are Chairman George K. Merz of Portland General Electric Co., Vice Chairman Keene R. Shogren of Northwest Natural Gas Co., and Secretary-Treasurer Robert D. Best of R. M. Wade & Co.

Guest speaker for the November 10 meeting was Gerald R. Fahey of Revere Copper and Brass Co., Los Angeles, Cal., who spoke on corrosion of copper and copper base alloys.

•

Los Angeles Section has scheduled E. Lee Crampton of the Long Beach Harbor Department as the guest speaker for the January 18 meeting. He will discuss general corrosion problems encountered by the Harbor Department.

T. R. Schmidt of Shell Development Co., Emeryville, Cal., talked on well casing wall thickness gauging instrumentation at the November 11 meeting.

•

San Diego Section Trustee F. O. Waters of the San Diego Utilities Department worked with R. C. Tullis recently to arrange for displays on the corrosion of various metals and some of the protective methods used to control corrosion. The displays were given at the International Association of Municipal Organizations held in San Diego. There were 450 delegates representing 22 countries at the meeting.

•

San Francisco Bay Area Section heard Allen G. Gray, editor of Metal Progress Magazine, speak on corrosion and metal technology of the 60's at the December 5 meeting.

Harold Templeton of Allied Steel Products is scheduled to speak on differences between castings and wrought materials for corrosion resistance for the January 10 meeting.

•

The 1961 Western Region Conference will be October 4-6 at the Hotel Multnomah, Portland, Oregon.

•

The 7th Annual Houston Section Corrosion Control Short Course will be held February 2-3 at the Rice Hotel, Houston.

•

The Shreveport Section will hold a corrosion short course February 14-15 at Centenary College, Shreveport, La.

Foreign Corrosion Reports

Corrosion Meeting Report From Spain

A report of the 11th meeting on corrosion of the European Federation of Corrosion held in Barcelona, Spain, October 26-27, 1960, has been received by the Inter-Society Corrosion Committee's Subcommittee on Relations with Foreign Organizations. The report printed below was submitted by ISCC correspondent J. M. Alameda.

Within the 32nd International Congress on Industrial Chemistry held in Barcelona October 23-30, the European Federation of Corrosion has celebrated its 11th Journee of Corrosion, this being the first time that such a meeting was held in Spain. It was organized by officers of the National Association of Spanish Chemists (ANQUE) and Instituto del Hierro y del Acero, two members of the Federation.

The main subject of the meeting dealt with corrosion problems by sulfur products, but other aspects of corrosion also were discussed.

Main lectures were given by G. Valensi of the University of Poitiers, J. Llopis of the Instituto de Qumica-Fisica Rocasohano, Madrid, P. Marchessaux of France and V. Gomez Aranda of the Instituto Nacional del Combustible, Zaragesa.

Although this was a European meeting, several American scientists and engineers attended the Congress. Captain J. E. Catlin of the U.S. Air Force and E. G. McLellan of the U. S. Department of the Navy presented an interesting paper about cathodic protection on pipelines and other USAF and U.S. Navy installations in Spain.

An "American Day" was celebrated on October 26. More than 20 American papers were presented. This special day was closed with a lecture on "Responsibility of Chemical Engineering to the Future" by F. J. Antwerpen, secretary of the American Institute of Chemical Engineers.

About 2,000 persons attended the congress including Spanish, German, Belgian and English representatives. Several attended from Yugoslavia and Hungary.

The Congress was complemented with social events, visits to industrial plants, educational centers, museums, etc., and visits to the Gothic Quarter of Barcelona.

COKE BREEZE

Backfill for Anodes

Ideally suited for use with anodes. Has a high carbon content and comes in sizes of ⅛-inch x 0 to ⅜ x ⅛ inch. In bulk or sacks. Prices on other sizes on request.

National Carbon Anodes
Magnesium Anodes
Good-All Rectifiers

WHOLESALE COKE COMPANY

PHONE GARDENDALE, ALA.
HEmlock 6-3603
P. O. Box 94 Mt. Olive, Ala.

New Method Used to Plate Steel With Aluminum

A new vapor deposition technique for plating steel with aluminum has been developed at Wright Air Development Division of Wright Patterson Air Force Base, Ohio.

Liquid tri-isobutyl aluminum, an organometallic compound, is introduced to the plating chamber as a vapor which is decomposed by heat at 500 F. Aluminum atoms are released and adhere directly to the suspended base metal. The technique may make practical the use of complex steel shapes and fasteners in oxidizing environments at 500 to 1000 F and lessen the danger of galvanic corrosion.

•

Greater Boston Section will hold a corrosion short course June 20-21 at the Wentworth Institute, Boston, Mass.

POSITIONS WANTED AND AVAILABLE

Active and Junior NACE members and companies seeking salaried employees may run two consecutive advertisements annually without charge under this heading, not over 35 words set in 8 point type. Advertisements to other specifications will be charged for at $12.50 a column inch.

Positions Wanted

Engineer—Six years' experience. Three years underground corrosion work, three years sales promotion of tape coating. Other experience, time study, cost control, extensive technical writing. BE in EE. Prefer Houston area. Resume on request. CORROSION, Box 60-32

Corrosion Engineer—Experienced in survey, design and installation of galvanic and impressed current cathode protection systems. Desires responsibilities with gas distribution or pipeline company in the mitigation of corrosion. CORROSION, Box 60-33.

Positions Available

Sales Engineers (5). Large progressive paint & plastics manufacturer expanding its sales force needs additional industrial paint and protective coating salesmen, Metropolitan New York area, Philadelphia area, Balto-Wash. area, Chicago area and Gulf Coast area. Unusual opportunity. Top salary & bonus, company benefits. CORROSION, Box 61 - 1.

Make SEA WATER -ANYWHERE!

SEA RITE SALT

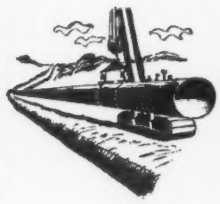
for CORROSION STUDIES

4½ oz. Sea Rite Salt crystals in one gallon tap water produces laboratory sea water quickly, inexpensively. Provides uniform, constant results based on 77 composite analysis. Immediate delivery — any quantity. Technical literature on request. Write, wire, phone now!

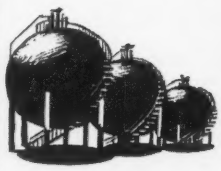
LAKE PRODUCTS CO., Inc.
ST. LOUIS 25, MISSOURI

BURNDY thermOweld®

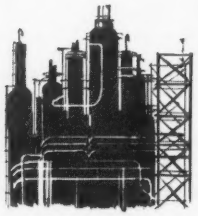
For Cathodic Protection



PIPELINE



GAS UTILITY



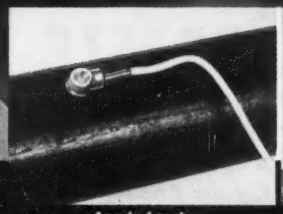
PETROLEUM

MARINE

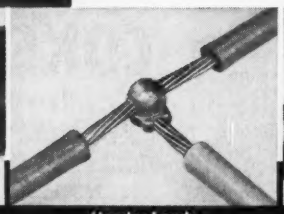
Wherever electrical connections are required in cathodic-protected installations, THERMOWELD assures corrosion-free, vibration-proof weld connections.

THERMOWELDER is compact, easy to fire, and easy to clean.

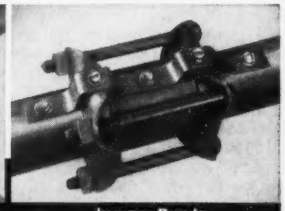
THERMOWELD powder fires everytime—starting powder can't mix with the welding charge, and the moisture-tight cartridge keeps the powder dry.



Anode Leads
Sounder, surer welds



Header Leads
Higher conductivity connections



Jumper Bonds
Easier strap or cable bonds

For complete details, call your Burndy representative or write:

BURNDY

60-15

NORWALK, CONNECT. • BICC—BURNDY Ltd., Prescot, Lancs., England • In Continental Europe: Antwerp, Belgium • TORONTO, CANADA

ADVANCE PROGRAM
17th Annual Conference and 1961 Corrosion Show

Hotel Statler-Hilton, Buffalo, N.Y.

March 13-17, 1961

Only Five Booths Still Available for '61 Corrosion Show

All booths except five have been assigned at publication time for the 1961 Corrosion Show to be held in conjunction with NACE's 17th Annual Conference in Buffalo, N.Y., March 13-17. All booths probably will be sold in the next few weeks, according to R. W. Huff, Jr., NACE Exhibits Manager.

The latest methods, techniques, equipment and services for controlling industrial corrosion will be exhibited in the booth displays on the Mezzanine Floor of the Hotel Statler-Hilton, headquarters for the conference. Qualified men from the exhibiting companies will be on hand at the booths to answer specific questions on corrosion control problems.

A list of the exhibitors by booth numbers and a partial list of products to be exhibited are given on Page 55.

The show will be open from 10 a.m. to 5 p.m. Tuesday, Wednesday and Thursday. No technical symposia meetings are scheduled for Tuesday afternoon so that conference registrants can have free time to visit the booths.

Registration Will Begin Sunday, March 12 at 1 pm

Registration for the Buffalo Conference will begin at 1:30 p.m., Sunday, March 12, on the Mezzanine of the Hotel Statler-Hilton. Complete schedule of registration hours is given below.

Registration fees (including a banquet ticket) for members will be $25, $30 for non-members and $20 for ladies. Partial registration fee (no banquet ticket) will be $15 for members, $20 for non-members and $10 for ladies. Banquet tickets purchased separately from registration will be $12 each.

Registration Schedule

Sunday	1:30 p.m.- 5:00 p m.
Monday	7:30 a.m.- 4:30 p.m.
Tuesday	7:30 a.m.- 4:30 p.m.
Wednesday	8:00 a.m.- 4:30 p.m.
Thursday	8:00 a.m.- 4:30 p.m.
Friday	9:00 a.m.-11:00 a.m.

General Business Meeting

The annual general business meeting for all NACE members will be held at 11 a.m., Wednesday, March 15, during the Buffalo Conference. Actions of the NACE Board of Directors will be ratified and reports heard from officers and standing committees of the association as listed below.

Agenda

Opening remarks and report of the President, George E. Best
Report of the Vice President, Edward C. Greco
Report of the Treasurer, C. G. Gribble, Jr.
Report of Standing Committee Chairmen:
A. Publication Committee Chairman R. S. Treseder
B. Regional Management Committee Chairman W. F. Fair, Jr.
C. Technical Practices Committee Chairman T. J. Maitland
D. Policy and Planning Committee Chairman R. A. Brannon
E. Inter Society Corrosion Committee Chairman R. R. Pierce
Report of Executive Secretary T. J. Hull
Ratification of Actions taken by Board of Directors
New Business
Closing remarks of President George E. Best

Gamut of Industrial Corrosion Problems Included on Program

Corrosion problems related to a wide gamut of industries ranging from corrosion control on missiles and cathodic protection of ships to application of epoxy, urethane and polyethyer polymer protective coatings will be discussed during the technical program of the 17th Annual NACE Conference to be held March 13-17 at the Hotel Statler-Hilton in Buffalo, N.Y.

This technical program will include presentation of about 80 papers on a variety of corrosion problems. These papers will represent the research work and experience of 120 authors from about 100 companies in the United States and Canada.

Corrosion papers will be presented in 15 symposia: cathodic protection, chemical industry, elevated temperatures, general corrosion, high purity water, inhibitors, marine corrosion, missile industry, oil and gas production, pipeline general, plastics, corrosion principles, protective coatings, refining industry and utilities.

A time schedule of the 15 symposia with abstracts of papers to be presented are given chronologically on Pages 47-55 of this issue.

Included in the Buffalo technical program will be 52 NACE technical committee meetings and the Inter Society Corrosion Committee. A schedule of these meetings is given in a table on Page 46.

All conference activities including the Fellowship Hour, banquet, technical program and 1961 Corrosion Show will be held in the Hotel Statler-Hilton. Details of conference activities are given on succeeding pages of this issue.

An advance program and other information on the Buffalo Conference is being mailed to NACE members and domestic subscribers of CORROSION. Hotel registration cards will be included.

NACE Books Scheduled For Sale at Booth

Some of NACE's books and pamphlets are secheduled to be available for sale at the NACE booth during the Buffalo Conference. The booth will be at the Corrosion Show in the Hotel Statler-Hilton.

The booth also will be an information center for the conference and will have a display of NACE literature. Orders will be taken on books and pamphlets.

Membership application blanks and information on 1961 regional meetings and short courses will be available.

Orders for copies of technical papers presented at the Buffalo Conference will be taken at the NACE booth.

Annual Banquet to Be Highlight of Buffalo Social Activities

Highlight of social activities of the Buffalo Conference will be the annual banquet to be held Wednesday evening, March 15 at the Hotel Statler-Hilton. Entertainment and a dance afterwards have been scheduled.

Other features of the banquet will be presentation of the NACE awards including the 1960 Whitney Award to H. R. Copson of International Nickel Company's Research Laboratory, Bayonne, N.J., and the 1960 Speller Award to Kenneth G. Comton of Bell Telephone Laboratories, Inc., Murray Hill, N.J. (See Page 39 of the December issue of CORROSION.)

Presentation also is scheduled of the NACE Young Author Award for the best technical paper published in CORROSION by an author 30 years of age or younger.

New officers and directors of the association will be introduced to the members at the banquet. These men will assume their offices at the conclusion of the Buffalo Conference. (See Page 46, December issue.)

Other social activities of the conference include a Fellowship Hour scheduled for Tuesday evening, March 14, and a special program for the ladies attending the conference.

ADVANCE PROGRAM
17th Annual NACE Conference
March 13-17, Buffalo, N.Y.

What NACE Can Do For Management to Be Discussion Topic

A new discussion session entitled "What NACE Can Do For Management" will be included in the 17th Annual NACE Conference in Buffalo, N. Y. Four speakers have been scheduled to participate in the round table discussion.

Discussion will include experiences of the speakers with NACE activities they have led and benefits their companies have received from participation in NACE activities.

The four speakers for the panel are Hugh P. Godard of Aluminium Laboratories, Ltd., Kingston, Ontario, Canada, who is past president of NACE; Andrew R. Murdison, the Pipe Line Division of Imperial Oil, Ltd., Toronto, Canada; Walter H. Burton, manager of Materials Engineering with Allied Chemical Corporation, Camden, New Jersey; and S. John Oechsle, Jr., president of Metalweld, Inc., Philadelphia, Pa.

This panel discussion will be held at 2 pm, Tuesday, March 14, in the Golden Ballroom of the Statler-Hilton Hotel. Chairman of the discussion period is L. W. Gleekman of Wyandotte Chemical Co., Wyandotte, Mich.

Program Includes Two Roundtable Discussions

Two roundtable discussion sessions are included in the technical program for the Buffalo Conference. They will be on general corrosion problems and on pipeline and underground corrosion. Both are scheduled for 9 a.m., Friday, March 17.

Chairmen for the roundtable on general corrosion problems are John J. Halbig, Sr., Armco Steel Corp., Middletown, Ohio. Paul C. Hoy of Dayton Power & Light Co., Dayton, Ohio and L. H. West of Standard Oil Co., Fostoria, Ohio, are chairmen of the roundtable on pipeline and underground corrosion.

Discussions at the two roundtable sessions will be on questions submitted by NACE members.

NACE Reviews Papers Given at Meetings For Publication

Technical papers presented at NACE meetings will be published after review and approval by the NACE Editorial Review Subcommittee. Thereby, persons interested in technical material presented at a conference will have access to the information in CORROSION Magazine, which is indexed extensively by NACE and by other agencies.

Corrosion workers concerned with technical literature originating with and published by NACE are invited to write to the association's headquarters at 1061 M & M Bldg., Houston 2, Texas, for copies of the NACE Literature List.

The association does not publish a proceedings of its meetings. Publication of technical papers usually follows their presentation by a few months because of the time required for review, editing and revision.

The association also considers for publication technical articles submitted voluntarily on any phase of corrosion control problems.

Tentative Technical Committee Schedule of Meetings

Monday March 13 am	T-1 T-2C-1 T-2J	T-5A-1 T-5A-3 T-6G
Monday March 13 pm	T-2H T-3G-1 T-4C T-4F T-4F-1	T-4F-2 T-4G T-4H T-5A T-5A-2
Tuesday March 14 am	T-2C T-2D T-2M	T-3F T-4B T-4J
Tuesday March 14 pm	T-5D	
Wednesday March 15 am	T-3H T-4A T-4A-3 T-4E	T-4E-1 T-5E T-6A T-6J
Wednesday March 15 pm	T-2E T-3A T-3B	T-5B T-6B T-8A
Thursday March 16 am	T-2 T-3 T-5 T-6F	T-7 T-7B T-8
Thursday March 16 pm	ISCC* T-3D T-3E T-3E-1	T-4 T-6 T-6D T-8

* Inter-Society Corrosion Committee.

Procedure Improved For Ordering Copies Of Papers

Improvements have been made in the procedure for handling orders for copies of technical papers to be given at the 1961 NACE Buffalo Conference. The revised procedure is as follows:

1. Orders will be taken at Buffalo for copies of papers to be printed by NACE at a uniform price of 50 cents per copy, payment with order.

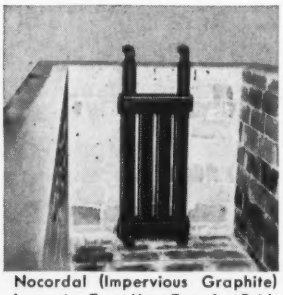
2. A list will be published in April issue of CORROSION of papers to be printed by NACE. Orders will be accepted at 50 cents per copy for these papers from persons attending the conference. Orders from persons who did not attend will be accepted at $1 a copy.

3. Order forms will be at the NACE booth at the Corrosion Show.

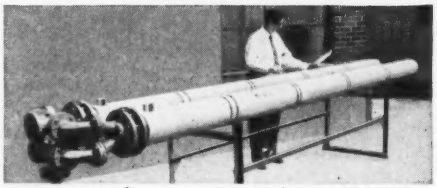
Papers ordered from NACE will be printed and forwarded within six weeks after the Buffalo Conference.

HEIL of Cleveland

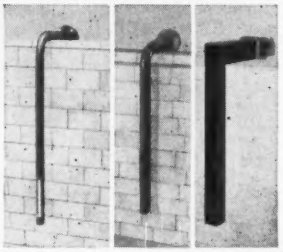
Headquarters for TANK HEATING and AGITATION



Nocordal (Impervious Graphite) Immersion Type Heat Transfer Grid.



HEIL Nocordal (Impervious Graphite) External Heat Exchanger for Heating Sulphuric Acid Anodizing Solution.



HEIL Rigidex Plastic Steam Jet Agitator. HEIL E-3-B Lead Steam Jet Agitator. Nocordal Steam Jet Agitator.

● Complete facilities for heating and agitating any pickling, plating, anodizing or other tank solution. Continuous or batch processing. Proven acid-resistant construction. Let the Heil engineers with 30 years experience recommend the equipment that will provide utmost efficiency, economy and maintenance-free operation.

Write for Fully Descriptive Bulletins Today.

CHEMICAL PROOF LININGS · TANKS HEATERS PLASTICS

HEIL PROCESS EQUIPMENT CORPORATION

12922 Elmwood Ave. • Cleveland 11, Ohio

ADVANCE PROGRAM
17th Annual NACE Conference
March 13-17, Buffalo, N.Y.

Refining Industry

Session One, Monday, March 13, 9 am

Chairmen: F. B. Hamel, Standard Oil Co., Cleveland, Ohio, and G. C. Hall, Richfield Oil Corp., Wilmington, Cal.

Effect of Redox on Refinery Corrosion, by C. B. Hutchison and W. B. Hughes, Petrolite Corp., St. Louis, Mo.
Discusses effect of sulfide available to corrode refinery crude unit overhead equipment. Oxidation reduction potential (redox) used as criterion of sulfide content. Study shows that optimum operating conditions are established through careful injection of ammonia to control pH, redox and sulfide content of overhead water. Laboratory data are given to show influence of changes of pH and redox on corrosivity and on effectiveness of various corrosion inhibitors. Illustrates application of findings to refinery practice.

Oxidation of Iron-Chromium Alloys, by D. Lai and R. J. Borg, Lawrence Radiation Laboratory, Livermore, Cal., and M. J. Brabers, Belgian Atomic Energy Laboratories, Mol, Belgium and J. D. Mackenzie, General Electric Research Laboratory, Schenectady, N. Y., and C. E. Birchenall, University of Delaware, Newark, Del.
Discusses mechanisms by which steels are made oxidation resistant at high temperatures as possible means to improve their performance. Oxidation rates of iron alloys containing 0.2 to 10 percent chromium have been measured from 750 to 1025 C. Nature of products has been checked by metallography, X-ray diffraction and chemical analysis. At low chromium concentrations there is small increase in oxidation rate compared with pure iron for short times, but for longer times the rate diminishes. Rate at given temperature diminishes with increasing chromium concentration. Rate accelerations during isothermal measurement do not occur at reproducible times or average thicknesses, suggesting that scale fracture plays an important role. Mechanism for scale embrittlement is proposed. Also discusses ways in which chromium might contribute to a reduced oxidation rate of iron.

Catalytic Formation of Hydrogen Sulfide on Corroding Metal Surfaces, by A. S. Couper, American Oil Co., Whiting, Ind.
Under certain conditions, surfaces of corroding metals act as catalysts in forming corrosive hydrogen sulfide—either from its elements or from decomposition of organic sulfur compounds. In laboratory, catalytic activities of surfaces depend on composition of sulfidic stream, composition of corroding metal, duration of metal exposure, temperature and stream velocity. Principles learned in this study apparently explain certain phenomena in high temperature sulfidic corrosion of refinery processing equipment. Tentative conclusions designate areas of promising research to minimize high temperature sulfidic attack.

Influence of Variables on Corrosion of Copper-Base Alloys in Refinery Systems, by Mahmoud T. Dajani and David B. Boies, Nalco Chemical Co., Chicago, Ill.
Presents laboratory investigation of influence of variables on copper base alloy corrosion in hydrocarbon-water systems. Variables studied separately and in combination included pH, hydrogen sulfide, cyanide ion, chloride ion and dissolved oxygen. Alloys studied were Admiralty, 70-30 cupronickel and red brass, using electrical resistance corrosion probes and test coupons for determining corrosion rates and type of attack. Changes in potential of corroding specimen also were observed. Inhibitors were evaluated in system containing combination of above variables.

Inhibitors

Session One, Monday, March 13, 9 am

Chairmen: A. J. Freedman, Nalco Chemical Co., Chicago, Ill., and Robert Legault, General Motors Corp., Warren, Mich.

Inhibitors in Low Temperature Petroleum Refinery Service, by H. G. Bennett, British American Oil Co., Ltd., Toronto, Canada
Discusses arbitrary limit between low and high temperatures in oil refinery corrosion. Describes experience in corrosion caused by sulfur, salt and naphthenic acids. Control methods described are design, use of resistant materials, heat treatment, radiography and inhibitors. Also discusses economics of these methods. Case histories are given to prove or disprove economic superiority of inhibitors.

Inhibiton of Corrosion in Concentrated Lithium Bromide Solutions at Elevated Temperatures, by Norman Hackerman, University of Texas, Austin, and E. S. Snavely, Jr., and R. M. Hurd, Texas Research Associates, Austin, Texas

Low corrosion rates of mild steel have been achieved with proper adjustments of alkalinity, due to formation of a magnetite film which is protective only when deposited under conditions which result in formation of ferrous and ferrite ions at an optimum rate. Under some conditions at high temperatures, transparent deliquescent crystals form on steel surface and prevent formation of a continuous magnetite film.

Heat Transfer Testing of Cooling Water Treatments—Part 1: Laboratory Evaluation, by A. J. Freedman, W. J. Ryzner and J. D. Knapp, Nalco Chemical Co., Chicago, Ill.

Heat Transfer Testing of Cooling Water Treatments—Part 2: Field Evaluation, by B. J. Northan, G. Reid and P. R. Puckorius, Nalco Chemical Co., Chicago, Ill.

Missile Industry

Session One, Monday, March 13, 9 am

Chairmen: E. H. Phelps, United States Steel Corp., Monroeville, Pa., and H. L. Stevens, Wright-Patterson Air Force Base, Ohio

Nitrogen Tetroxide Corrosion Studies, by C. W. Alley, A. W. Hayford, and H. F. Scott, Jr., Allied Chemical Corp., Hopewell, Va.
Corrosion rates of carbon steel, stainless steel, aluminum and titanium in dry and wet nitrogen tetroxide were determined under static conditions of exposure at —9 C to 74 C. Carbon steel and aluminum were attacked in proportion to water concentration and temperature. Stainless steel Type 304L and titanium were unattacked, and stainless steel PH 15-7 Mo only slightly. Significant corrosion of 304L occurred in presence of Teflon. Corrosion by dry nitrogen tetroxide under flow conditions was negligible. Teflon was most resistant of plastics exposed to nitrogen tetroxide.

Investigation of Corrosion Mechanics of 2014 Aluminum Alloy in 50 w/o N_2H_4 - 50 w/o UDMH Aqueous Solution, by N. Ida, D. O'Keefe and J. T. Snyder, Martin Company, Denver, Colo.
Describes investigation to determine corrosion behavior of 2014 aluminum alloy in propellant fuel. Surface effects and oxide film stability were checked by electron microscope study. Total effects of water chloride ion and various conditional treatments of the 2014-T6 alloy were analyzed by a three parameter cubic analysis. Data also presented to correlate room temperature exposure data to accelerated temperature tests.

Investigation of Corrosion Effects From Long Term Exposure of Various Materials in Nitrogen Tetroxide and 50-50 Aerozine-UDMH Propellants, by R. Breyer, H. Brown and N. Jennings, Martin Company, Denver, Colo.
Describes investigation to determine effects on numerous metallic and non-metallic materials from long term exposure to nitrogen tetroxide and 50-50 hydrazine-UDMH (50 percent hydrazine, 50 percent UDMH, by weight). Exposures were performed in propellants of various water contents in sealed containers at 55 to 60 F. Also included effects of applied stress and such fabrication processes as heat treatment, welding and mechanical fasteners. Correlations were made on severity of attack in relation to water content of propellant.

Impact Ignition Sensitivity of Titanium and Aluminum in Liquid Fluorine, by Charles J. Sterner and Alan H. Singleton, Air Products Inc., Emmaus, Pa.
Describes experimental program to investigate pyrophoric properties of titanium alloy A 110 AT and aluminum alloy 6061 in liquid fluorine. Initiation was provided by intensive impact using a variety of striker configurations and impact energies to 60 ft/lb. Discusses development and design of suitable impact tester. Results show ignition sensitivity of titanium at any impact level varies markedly with geometry of striking surface. Proposes a mechanism to explain that liquid fluorine-titanium ignitions do not propagate. Aluminum was insensitive to impact-ignition in liquid fluorine.

Refining Industry

Session Two, Monday, March 13, 2 pm

Temperature Dependence of Vanadium Corrosion in Oil Fired Boilers, by N. D. Phillips and C. L. Wagoner, Babcock & Wilcox Co., Alliance, Ohio
Benefits to be gained from use of higher steam temperatures in oil fired boilers warranted laboratory investigation of oil-ash corrosion of superheater alloys. Program included pilot plant corrosion tests and use of differential thermal analysis techniques. With a given alloy, extent of oil-ash corrosion is dependent principally on metal temperature, combustion gas temperature and fuel composition. Minimum metal temperature for initiation of corrosion is dependent on deposit composition. Tests with additives to reduce corrosion showed that for most effective reduction, deposit temperatures should exceed reaction temperature for given additive-ash composition.

Corrosion Data on Admiralty Exchanger Tubes, by D. B. Deboies, Nalco Chemical Co., Chicago, Ill.

Effect of Temperature and Velocity on Corrosion of Admiralty, by representative from Esso Research and Engineering Co., Linden, N. J.

Corrosion Characteristics of Iron-Aluminum and Iron-Chromium-Aluminum Alloys in the Petroleum Industry, by R. B. Setterlund and G. R. Prescott, C. F. Braun Co., Alhambra, Cal.

ADVANCE PROGRAM
17th Annual NACE Conference
March 13-17, Buffalo, N.Y.

Protective Coatings

Session One, Monday, March 13, 2 pm

Chairmen: Newell D. Casdorph, Union Carbide Chemicals Co., Port Lavaca, Texas, and J. P. Ferraro, American Cyanamid Co., Bound Brook, N. J.

Painter Safety, by L. S. Hartman, Hartman-Walsh Painting Co., St. Louis, Mo.
Outlines first step as medical examination of employees. Other topics include proper handling and storage of coating materials, protective apparel, check list for toxic materials, rigging and scaffolding, explosion hazards, equipment safety checks and protection against dermititis and respiratory protection.

Commercial Hot-Dip Galvanizing of Fabricated Items Used in Construction of Industrial Projects, by L. R. Vickers, Nowery J. Smith Company, Houston, Texas
Gives non-technical discussion of fundamental steps used in commercial hot-dip galvanizing. Illustrates general composition of alloy layers and explains different appearances expected. Gives case histories comparing life of galvanized structures and shows why some structures outlast others. Details given on comparison of cost between galvanizing and other types of coatings, including organic and inorganic. Explains some misunderstandings of galvanizing in general and suggests aids for designing material to be galvanized.

Use of Color Standards for Surface Preparation, by S. John Oechsle, Jr., Metalweld, Inc., Philadelphia, Pa.
Describes physical use of Swedish and domestic color standards for surface preparation on actual contract jobs on which standards were included as specifications. Reviews existing color standards and suggests possible modifications for more practical use.

Spray Application of Heavily Filled Resinous Coatings, by J. H. Cogshall and A. M. Smith, Pennsalt Chemicals Corp., Natrona, Pa., and T. McRitchie, Quikspray, Inc., Port Clinton, Ohio

Missile Industry

Session Two, Monday, March 13, 2 pm

Corrosion Protection for Polaris Missile, by Milton F. Williams, Lockheed Missiles & Space Division, Sunnyvale, Cal.
Outlines basic concepts of corrosion protection and finishing of fleet ballistic missiles. Discusses light weight, high strength materials used in missile fabrication correlating associated problems of single and complex corrosion. Probable corrosion problems from combinations of dissimilar metal assemblies are reviewed with protective measures taken to produce effective long term storage. Data and photographs illustrating typical case histories are included.

Stress Corrosion Cracking of Solid Rocket Case Materials, by R. B. Robinson, Aerojet-General Corp.

Stress Corrosion Problems of High Strength Materials for Air Force Missile and Vehicle Application, by Howard W. Zoeller and Lt. William F. Payne, Wright-Patterson Air Force Base, Ohio
Stress corrosion failures have occurred in high strength aluminum alloys, high strength low alloy steels and martensitic stainless alloys. Failure experiences of recent years are reviewed with corrective techniques used.

Study of the Titanium-Lox Reaction, by W. K. Boyd and J. D. Jackson, Battelle Memorial Institute, Columbus, Ohio, and A. W. Brisbane, Wright-Patterson Air Force Base, Ohio
Report on investigation of titanium's impact sensitivity in contact with liquid oxygen that indicated that combination of factors occurring in proper sequence are necessary to trigger the reaction. Proposes that reaction proceeds only with oxygen in gaseous phase. During impact in lox, gaseous oxygen is generated and compressed. Imperfections on surface acts as focal points for rapid heating. Propagation of reaction depends on heat loss to surrounding area.

Chemical Industry

Session One, Tuesday, March 14, 9 am

Chairmen: Otto H. Fenner, Monsanto Chemical Co., St. Louis, Mo., and Charles W. Ambler, Jr., American Zinc, Lead & Smelting Co., East St. Louis, Ill.

Corrosion of Niobium and Tantalum in Alkaline Media, by Irvine I. Tingley and R. R. Rogers, Department of Mines and Technical Surveys, Ottawa, Canada.

Designing Corrosion Out of Chemical Processing Equipment, by R. Sanford, Nooter Corporation, St. Louis, Mo.

Stream Pollution Control: Corrosion in Biological Treatment of Chemical Process Industry Wastes, by O. W. Siebert, Monsanto Chemical Co., Monsanto, Ill.
Data given on results of tests to determine range of acceptable construction materials for all unit operation of chemical plant waste disposal facility. Illustrates corrosion problems encountered in biological treatment of chemical wastes and stream pollution abatement. Tests were conducted in pilot plant installed to study treatability of wastes on continuous basis. Corrosion study was directed toward criterion requirements for design and economical maintenance of a full scale secondary waste treatment plant. Recommendations for construction materials are given.

Influence of Impurities on High Temperature Corrosion Properties and Reaction Kinetics of Zirconium in Hydrochloric Acid, by W. E. Kuhn, Carborundum Company, Niagara Falls, N. Y.
Corrosion of zirconium of four different analyses at 150 to 250 C is discussed. Studies were made of reaction kinetics and surface phenomena. Results of experimental work are discussed with details given on role of impurities, heterogeneous nature of corrosion, influence of electrolyte, surface preparation and diffusion barriers. Concludes that in geneal small concentrations of specific impurity elements which formed precipitate phases had powerful influence on dissolution rate of zirconium and resistance of primordial oxidic protective films. Also found that solution heat treatments improved corrosion resistance of zirconium in hydrochloric acid.

Protective Coatings

Session Two, Tuesday, March 14, 9 am

Comparative Properties of Major Types of Urethane Coatings, by J. W. Cushing, Carboline Company, St. Louis, Mo.
Describes basic differences in form, composition and end uses of major types of urethane (or polyurethane) surface coatings commercially available. Illustrates considerable variation in chemical resistance in two-package or catalyzed urethane group, most useful urethane for corrosion resistant maintenance coatings. Describes superior resistance of catalyzed urethanes to softening by high solvency organics as compared to commercial epoxy-amine coatings. Illustrates urethanes' retention of flexibility and impact resistance after weathering exposures as compared to commercial catalyzed epoxies. Briefly describes several types of urethane coatings of interest but not available yet commercially.

Versamid Epoxy Coatings—Corrosion Applications, by Harold Wittcoff, Don E. Floyd and David W. Glaser, General Mills Central Research Laboratories, Minneapolis, Minn.
Discusses five-year exposure tests to show superior resistance of versamid epoxy coatings to amine cured epoxy resins and vinyls. Discusses marine, oil industry, exterior and interior pipe lines and steam resistant formulations. Also describes uses with glass fiber and other reinforcing materials for patching rusted metal surfaces. Describes formulations for standard solvent based primers and topcoats, solventless coatings, zinc dust primers and variety of other compositions.

Protective Coatings for High Temperature Service, by Gatewood Norman, Firestone Tire & Rubber Co., Orange, Texas
Describes problems encountered in using various high temperature coatings. Screening tests were conducted and results given. Types of surface preparations used are illustrated and results obtained. Also discusses major points of interest in use of primers in high temperature coatings.

Chemically Resistant Polyether Polymer as a Coating Material, by B. H. Mahlman, Hercules Powder Co., Wilmington, Del.
Reviews physical and chemical properties of a chlorinated polyether polymer (Penton) and relates them to properties required of a corrosion resistant coating material. Describes applications by solution, dispersion and dry-powder techniques. Properties and chemical resistance of applied coatings are discussed.

Oil and Gas Production

Tuesday, March 14, 9 am

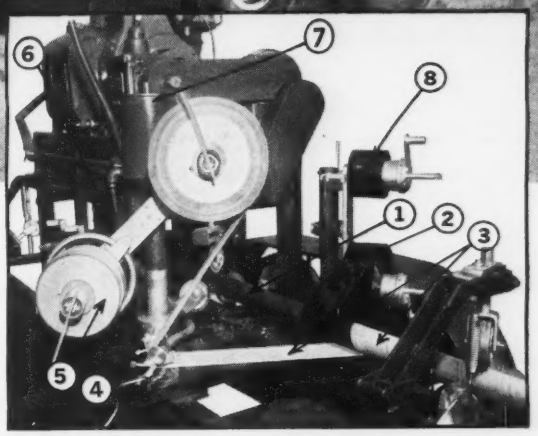
Chairmen: W. C. Koger, Cities Service Oil Co., Bartlesville, Okla., and J. A. Caldwell, Humble Oil & Refining Co., Houston, Texas

Titanium: Use in Oil Production Equipment, by Ricardo Molina and F. W. Jessen, University of Texas, Austin, Texas

Investigation report on suitability of titanium in several specific applications in oil production. Use of titanium is suggested in equipment used in two principal artificial lifting methods—gas lift and plunger pumps. Material is adaptable because of resistance to corrosion and erosion. Results of laboratory experiments and field tests are given. Titanium is economically comparable with other alloys generally used in similar service.

A Costly By-Product of Corrosion—Gas Injection Well Plugging, by K. V. Terrell, W. E. Grubb and C. V. Chapman, Atlantic Refining Co., Dallas, Texas
Corrosion products entrained with other materials in injection gas can cause minor or severe plugging problems at formation face in gas injec-

NEW TECHNIQUE ASSURES PERFECT ON-SITE COATING



Pipe (coming toward you) spins through machine . . . undergoes dynamic cleaning from twin-powered brush heads. Coating comes off brake-type tape drum. Outer wrapping runs through fast-gluing adhesive attachment.

1. Spinning pipe
2. Polyken tape coating
3. Outer wrap
4. Glue applicator
5. Stand-by outer wrap turret
6. Power brush heads
7. Glue tank
8. Stand-by tape turret

POLYKEN QUALITY PLUS UNIQUE APPLICATION METHOD MAKE TOP SITE-WRAP COMBINATION

Your protective coating results are only as good as the material you use and the way you put it on. And with Polyken tape . . . plus the special, new Polyken way of on-site application . . . you get a combination that really does a perfect job —*simply, speedily, economically.*

Simplicity? Right! The completely mobile machine sets up in an hour (knocks down in half that time), uses 6 men or less for continuous cleaning, coating, and wrapping. Speed? You can process up to 20,000 lineal feet a day, take 10-minute breaks to switch pipe sizes. Economy? Look at it this way: You get *quality* tape, properly applied by a high-speed *quality* process. The result can't help meaning more *dependable* coating for your dollar.

For the full story on both machine and tape, visit us at Buffalo exhibit booths #2 and #3.

Polyken®

Experienced in modern PROTECTIVE COATINGS

THE KENDALL COMPANY
Polyken Sales Division

ADVANCE PROGRAM
17th Annual NACE Conference
March 13-17, Buffalo, N.Y.

tion wells. Corrosion problem and plugging problem are more severe when injection gas contains hydrogen sulfide, carbon dioxide or oxygen and when gas is not properly dehydrated. Remedial well treatments under these conditions can be expensive. Discusses nature and origin of plugging agents in typical injection gas, loss of injectivity experienced under different conditions, problems of treating wells to restore injectivity and checks and controls to insure clean gas or good quality is injected.

Casing Inspection Tool—An Instrument for In Situ Detection of External Casing Corrosion in Oil Wells, by T. R. Schmidt, Shell Development Co., Emeryville, Cal.

A surface recording, down hole instrument for detection of external corrosion in oil wells is described. It is a non-contacting, eddy-current instrument which measures and records casing wall thickness. Equations are presented to describe tool's action. Examples of laboratory and down-hole logs are shown to demonstrate tool's response to general thinning, pits, holes, collars, etc.

Corrosion Principles

Wednesday, March 15, 8:30 am

Chairmen: C. P. Dillon, Union Carbide Chemicals Co., Charleston, W. Va., and W. K. Boyd, Battelle Memorial Institute, Columbus, Ohio

Fundamentals of Corrosion of Copper and Its Alloys, by M. F. Obrecht, Michigan State University, East Lansing, Mich.

Deals with some fundamental theories and mechanisms involved in corrosion of copper and its alloys in water, particularly in high quality water. Also deals with some theory of corrosion of copper by absolutely pure water and effect of certain common ions. Covers theory developed on test program for determining corrosion rate and some results of fundamental laboratory studies on mechanisms of cause of corrosion. Reviews tests on copper and copper base alloys on types of water quality and significance of temperature and velocity on copper's corrosion rate. Effect of oxygen and carbon dioxide also considered.

Basis for Design of Aluminum Alloys for High Temperature Water Service, by R. L. Dillon and H. C. Bowen, General Electric Co., Richland, Wash.

Describes GE's Hanford Laboratories experience in preparing and corrosion testing aluminum alloys for high temperature water service. Effects of nickel and iron content, also minor additions and impurities are evaluated. Significance of casting variables is examined in terms of metallography and corrosion behavior. Tentative mechanism is proposed to explain necessity for finely dispersed Fe-Ni-Al second phase in achieving satisfactory corrosion resistance in high temperature water.

Corrosion Products, by A. H. Roebuck, Westco Research, Fort Worth, Texas

Mechanisms of Stress Corrosion Cracking, by E. H. Phelps, United States Steel Corp., Monroeville, Pa.

Elevated Temperature

Session One, Wednesday, March 15, 8:30 am

Chairmen: David Roller, Magna Products, Inc., Santa Fe Springs, Cal., and Anton deS. Brasunas, American Society of Metals, Novelty, Ohio

High Temperature Thermal Protective Systems, by S. W. Bradstreet, Armour Research Foundation, Illinois Institute of Technology, Chicago, Ill.

Discusses stability of coatings as affected by characteristics of interfacial zone at high temperatures. A working philosophy for coating research is illustrated by selecting a refractory metal and a mixed oxide and by discussing properties which each must exhibit to form a protective coating at high temperatures.

Development of Oxidation Resistant Columbium Alloys for Use in High Temperature Environments, by S. T. Wlodek, General Electric Co., Cincinnati, Ohio.

Summarizes advances made in developing oxidation resistant columbium alloys for nuclear and high strength applications. Oxidation mechanisms of some promising compositions are discussed. Also summarizes interplay between strength, fabricability and oxidation resistance. Includes discussion on use of coatings for long term protection.

Testing and Evaluation Thermal Protective Systems, by W. L. Aves, Chance Vought Aircraft, Inc., Dallas, Texas

Before being put in service, functional suitability of each high temperature structural system is evaluated and reliably established by screening tests and tests which simulate operational conditions. Screening tests are described with operational condition tests used to simulate re-entry, rocket blast, jet afterburner exhaust and engine exhaust.

Air Force High Temperature Materials Program, by Lt. James R. Myers, Wright Patterson Air Force Base, Ohio

Severity of thermal environments experienced by advanced Air Force vehicles requires use of new concepts in application of materials. Thermal protective schemes based on use of refractory metals, ceramics and combinations appear to be most promising. Future Air Force materials requirements are discussed with programs designed to meet them: (1) metal-ceramic composites for temperatures to 4000 F, (2) structural use of molybdenum and columbium alloys, (3) protective coatings for refractory metals and (4) development of test techniques to evaluate materials performance in anticipated enviornments.

Inhibitors

Session Two, Wednesday, March 15, 8:30 am

Polarization Techniques in Corrosion Research, by A. C. Makrides, Socony Mobil Oil Company, Inc., Dallas, Texas

Reviews use of polarization methods in corrosion research. Gives detailed description of experimental techniques applicable to systems commonly encountered. Analyses of typical sets of data illustrate use of such measurements in determining corrosion mechanisms. Includes oxidizing and non-oxdizing inhibitors. Special problems arising in solutions of low conductivity are given.

Problems in Determination of Corrosion Rates by Polarization Resistance and Overvoltage-Intercept Methods, by E. L. Koehler, Continental Can Co., Chicago, Ill.

Reproducible cathodic polarization data, which yield accurate corrosion rates by either polarization resistance or overvoltage-intercept methods, can be obtained in practical, electrochemically impure corroding systems. Emphasizes that good understanding of corroding system is desirable because, in any given case, conditions might nullify either method.

Inhibition Studies in Reactor Decontaminants, by Ronald D. Weed, General Electric Company, Hanford Laboratories, Richland, Wash.

Dibasic ammonium citrate solutions have shown promise as decontaminants for high temperature water recirculating systems when preceded by alkaline permanganate solution. Ammonium citrate solutions, when used at effective conditions, give corrosion rates which are above maximum desired rate in a nuclear reactor system containing carbon steel piping and other materials. Several organic compounds were evaluated as inhibitors in solutions designed for decontamination of nuclear reactor systems. Of compounds tested, tripropylamine and tri-n-dodecylamine proved to be most effective in solutions at 85 C.

Chemical Industry

Session Two, Wednesday, March 15, 2 pm

Corrosion Research and Control in Eldorado's Beaverlodge Mill, by G. F. Colborne, A. R. Allen and A. Thunaes, Eldorado Mining and Refining Limited, Saskatchewan, Canada.

Describes case history of severe corrosion in pressure leaching vessels and other parts in Beaverlodge mill soon after start-up in 1953. Investigations and tests on several protective coatings and construction materials were made while determining basic corrosion mechanism involved. Three different types were recognized: differential aeration cells, acid attack in sulfide-rich zones and general acceleration by low pH (below 9.5). Control measures involved maintenance of high pH by solution salt concentrations, organic coatings in areas subject to mild attack and Type 316 stainless steel in areas subject to severe attack under high temperature conditions.

Gasketing Problems in the Chemical Industry, by Charles M. Hobson, Garlock Packing Co., Camden, N. J.

Ultrasonics in Corrosion Inspection, by John E. Bobbin, Branson Instruments, Inc., Stamford, Conn.

Corrosion Mitigation in a Resin-in-Pulp Machine in Uranium Extraction, by C. W. Ambler, Jr., American Zinc, Lead and Smelting Co., East St. Louis, Ill., and Theodore F. Izzo, Uranium Reduction Co., Moab, Utah.

General Corrosion

Wednesday, March 15, 2 pm

Chairmen: Jerome M. Bialosky, Koppers Company, Inc., Verona, Pa., and Frank H. Beck, Ohio State University, Columbus, Ohio

Panel Discussion: Tools and Techniques for Solving Corrosion Problems, by Bernard Husock, Harco Corp., Cleveland, Ohio, Walter K. Boyd, Battelle Memorial Institute, Columbus, Ohio, R. B. McIntosh, Sherritt Gordon Mines Ltd., Alberta, Canada, and J. M. Bates, Union Carbide Chemicals Co., South Charleston, W. Va.

Sinter Plant Corrosion Problems, by R. J. Schmitt, United States Steel Corp., Monroeville, Pa.

Describes corrosion problem that occurs in exhaust gas system of a large sinter plant used to agglomerate iron ore fines. Corrosion of this carbon steel system was due to condensation of sulfurous and sulfuric acids and hydrochloric acid from exhaust gases. Discusses possible methods of minimizing future corrosion such as maintaining operating temperatures above acid dew point, insulating equipment exposed to weather and use of protective coatings. Outlines electrical resistance, ultrasonic and corrosion specimen test methods.

Keep your
crews busy
all year 'round

with **CARBO ZINC 11***

the all-weather maintenance coating

Most maintenance paints cannot be applied below 40° F. Not so with Carbo Zinc 11 . . . *the only protective coating that can be applied outdoors in cold weather.* Paint *anytime*, 12 months of the year, indoors or out . . . keeping a *smaller* crew busy full time. You still get protection far superior to standard maintenance paints.

- a zinc-filled inorganic protective coating
- water insoluble 20 minutes after applying
- fast drying, long-lasting galvanic protection for steel
- apply in humidity up to 95%, temperatures from –20° F. to 150° F.
- excellent resistance to water, coastal environment, brine, humidity, solvents

Use Carbo Zinc 11 without topcoat, or as primer with vinyl, Hypalon, epoxy, or inorganic topcoat. Resists undercutting and subfilm corrosion. Low material, application and maintenance costs.

Write for information, technical data, uses and samples. Also, see our catalog in CEC, pages 911-914.

6011

*Patent applied for

carboline COMPANY

32-A Hanley Industrial Ct. St. Louis 17, Mo.

Sales engineers in principal cities. Consult your telephone directory.

MAINTENANCE COATINGS WITH EXPERIENCE

ADVANCE PROGRAM
17th Annual NACE Conference
March 13-17, Buffalo, N.Y.

Cathodic Protection

Session One, Wednesday, March 15, 2 pm

Chairmen: Sidney Tudor, New York Naval Shipyard, Brooklyn, N. Y., and Herman S. Preiser, Navy Department, Bureau of Ships, Washington 25, D. C.

Low Potential Zinc Anode in Theory and Practice, By J. R. Wellington, Consolidated Mining and Smelting Company of Canada, Ltd., Trail, British Columbia, Canada

Briefly discusses principles of cathodic protection and basic requirements of a galvanic anode, then specifically examines anode requirements in terms of cathodic protection of iron or steel in electrolyte of uniform characteristics. Advantages of a low potential anode for protection of iron are discussed in terms of circuit resistance, self regulation and current distribution on cathode. It is shown that where cathode polarization controls current distribution on cathode and regulates anode current output, a new concept can be advanced for design of cathodic protection systems using low potential zinc anodes.

Cathodic Protection in the Brewing Industry, by Edgar W. Dreyman, Petro-Chemical Associates, Division of Riker Oil Co., Inc., Garden City, N. Y.

Deals with cathodic protection installations in various breweries. Discusses hot and cold water tanks, fermentation and storage tank protection. Gives details on use of galvanic and impressed current systems in pasteurizer sumps. Effect of cathodic protection on organic and glass coating will be included and type of anodes recommended for use in beer and brewing water. Five-year performance data on various equipment discussed and procedures outlined to obtain greatest efficiency from cathodic protection systems.

Economics of Cathodic Protection for U. S. Navy Ships, by R. C. Francis and F. E. Cook, Department of Navy, Bureau of Ships, Washington, D. C.

Incidence of corrosion on underwater areas of hull and appendages of Navy ships is discussed. A comparison between specific maintenance costs attributable to corrosion occuring from two successive drydockings of selected ship indicates significant savings achieved by use of sacrificial anode cathodic protection systems.

Plastics

Session One, Thursday, March 16, 9 am

Chairmen: John Delmonte, Furane Plastics, Inc., Los Angeles, Cal., and R. B. Seymour, Sul Ross State College, Alpine, Texas

Plastic Pipe Systems for Corrosion Resistance, by Allyn E. Webb and R. W. Johnson, Kraloy Plastic Pipe Co., Santa Ana, Cal.

Discusses corrosion resistance and heat limitations of materials available for plastic pipe systems such as PVC, Penton, etc. Describes products available such as pipe, conduit, fitting, valves, pumps and miscellaneous components. Also discusses special design considerations and gives examples of installations and their advantages over metal piping systems.

Unique Role of Plastics in Corrosion Control, by Raymond B. Seymour, Sul Ross State College, Alpine, Texas

Discusses wide use of plastics as functional materials in many fields such as coatings, linings, cements, pipe, molded parts and fabricated structures.

Effect of Different Types of Hardeners on Chemical Resistance of Epoxy Resins, by Frank E. Pschoor, Ciba Products Corp., Fair Lawn, N. J.

Three chemically different hardeners (anhydride, amine and boron trifluoride complex) were used to cure conventional liquid epoxy resin. Systems were checked for changes in flexural strength, weight and appearance after a six-month immersion in various chemical solutions. Strong organic solvents such as chloroform, acetone and tetrahydrofuran had an adverse effect on all systems. Cured systems were resistant to weak solvents such as hydrocarbons, alcohols or glycols. Anhydride cured systems showed better resistance to diluted acids; amine cured systems showed better results with diluted bases.

Elevated Temperature

Session Two, Thursday, March 16, 9 am

Hot Gas Corrosion of Fe-Ni-Cr Alloys, by E. A. Schoefer, Alloy Casting Institute, Garden City, Long Island, N. Y.

High Temperature Scaling of Hafnium, by J. D. Gadd, Case Institute of Technology, Cleveland, Ohio, and John D. Gadd, Thompson Ramo Wooldridge, Inc., Cleveland, Ohio

Scaling behavior of hafnium in air was studied in temperature range of 600 to 1200 C. Initially scaled at about a cubic rate which in time yielded to a much faster rate (breakaway) because of scale cracking. Breakaway phenomenon was associated with change from a dense black scale to a porous white scale. Both types were composed primarily of monoclinic oxide. Nitrogen also participated in scaling reaction because nitride was detected at metal-scale interface.

Corrosion of Superalloys by Selected Fused Salts, by A. Moskowitz and L. Redmerski, Crucible Steel Company of America, Pittsburgh, Pa.

Corrosion of Inconel X, Inconel 702, Rene 41, M-252 and WF-11 (Haynes 25) by potassium chloride and lithium fluoride at 1600 to 1900 F was studied. Thin coatings of salts caused severe corrosion of alloys in air which resulted in accelerated failures of thin sheet specimens in creep-rupture testing. Corrosion products consisted of oxides and spinels. Little if any corrosion occurred without oxygen. Presence of salt prevents normal formation of a protective oxide film. Corrosion occurred as severe surface attack with consequent eroding away of metal as intergranular penetration and as internal voids formed in alloy. All alloys were susceptible to each type of corrosion. Grain boundary separation effects due to 2500 to 10,000 psi stresses also were found.

Utilities

Thursday, March 16, 9 am

Chairmen: A. W. MacKay, Detroit Edison Co., Detroit, Mich., and Carl M. Thorn, Southwestern Bell Telephone Co., San Antonio, Texas

Effect of Mineral Impurities in Water on Corrosion of Aluminum and Steel, by Leonard C. Rowe and Monte S. Walker, General Motors Corp., Warren, Mich.

Discusses laboratory study made to determine effect of single or mixed impurities on aluminum or steel corrosion. Used conductance technique to determine corrosion rate variations. This method is based on concept that change in electrical conductivity of a thin metal strip reflects corrosion which has occurred. Effect of following minerals was determined: chloride, sulfate, bicarbonate, carbonate, calcium, magnesium and silicate. Chloride and sulfate were most detrimental to steel. No single impurity affects aluminum corrosion to degree that mixed impurities do. Solution containing soluble salts of copper, chloride, and bicarbonate accelerated aluminum's corrosion rate. Pitting depended on impurity concentration and temperature.

Iron Sulfate for Condenser Tube Corrosion Control, by Thomas W. Bostwick, Electric and Water Utilities Department, Jacksonville, Fla.

Discusses results of application of ferrous sulfate to surface condenser cooling water to extend condenser tube life by plating out a thin film of Fe_2O_3 on tube surface. Sharp reduction in tube failure rates resulted in all units. Daily use of ferrous sulfate at 1 ppm twice a day for periods of 30 minutes has been beneficial in reducing tube corrosion. Heat transfer rate at this concentration was not seriously affected through normal chlorination program was eliminated during six-month test. Indications are that ferrous sulfate could be used on intermittent or batch basis, thus giving protection at lower cost. Chlorination could be continued as necessary to maintain heat transfer.

Corrosion of Lead Cable Sheath, by K. G. Compton, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Discusses corrosion of lead under some circumstances. Explains that lead sheath is corroded by stray current and by galvanic cells. Examples of causes of corrosion are given.

Corrosion of Metals in Tropical Environments—Part 5: Stainless Steel, by B. W. Forgeson, C. R. Southwell and A. L. Alexander, U. S. Naval Research Laboratory, Washington, D. C.

Eight year exposure tests of six stainless steels to underwater and atmospheric environments in Panama Canal Zone are described. Stainless steels are not recommended for sea water service where perforation of structure is a consideration. Tropical atmospheres appear more corrosive to stainless than temperate climates.

Plastics

Session Two, Thursday, March 16, 2 pm

Corrosion Resistance of Room Temperature Cured Epon Resin Systems, by R. E. Burge, Shell Chemical Co., Union, N. J.

Evaluation of Rigid Plastics for Chemical Service, by L. S. VanDelinder, Union Carbide Chemicals Co., South Charleston, W. Va.

Discusses chemical stability of 11 different plastic construction materials exposed in 26 chemicals, primarily of organic chemical type. PVC, epoxy, phenolic, polyester, diepoxy and chlorinated polyether were investigated by weight change, dimensional change, hardness change, flexural strength, flexural yield and flexural modulus after 1, 3 and 6 month exposure to chemicals. Hardness testing as a rapid and simple means of determining condition of resin before and after exposure was most suitable method to determine effect of environment.

Design Considerations Involved in a New Reinforced Plastic Tank, by W. R. Wardrop and F. H. Humphrey, Metal-Cladding, Inc., North Tonawanda, N. Y.

Describes development and advantages of reinforced polyester and epoxy plastic tank construction incorporating helical cable windings on exterior to relieve plastic of much of stress of construction.

KENTUCKY PIPELINE CONSTRUCTION JOB SAVES TIME AND MONEY WITH ROSKOTE COLD-APPLIED MASTICS

Petroleum Exploration, Inc., specified the application of ROSKOTE PIPE MASTICS, by the ROSKOTER method in the construction of its new transmission pipeline from Manchester to London, Kentucky.

The results —

Dollar Savings by

elimination of heating fuel costs, loss from spillage, kettle operation and haulage.

reduction in size of coating crew, and amount of equipment required.

Time Savings resulting from

the continuous and steady application of two coats of quick-drying mastic with the ROSKOTER "minimum crew" coating device.

Superior Protection from Corrosion

because ROSKOTE MASTICS form a flexible pipe coating that is highly resistant to electrolytic action, deformation by soil stress, thermal influences and attack by moisture, acids, alkalies and salts.

These same savings and benefits can be achieved on your next pipeline project through the use of ROSKOTE COLD-APPLIED PIPE MASTICS. More than 400 gas and oil companies currently use these pipeline coatings which are adaptable for any application method such as brush, spray, glove or line travel operation to lines of any length and diameter.

Pipeline built from Manchester, Ky., to serve London, Ky.
Engineers: Petroleum Exploration, Inc., Lexington, Ky., and Sistersville, W. Va.
Contractor: Cumberland Contracting Co., Monticello, Ky.

ROYSTON LABORATORIES, Inc.
Blawnox, Pittsburgh 38, Pa.

A LEADER IN THE FIELD OF INDUSTRIAL COATINGS FOR CORROSION CONTROL

ATLANTA • CHICAGO • HOUSTON • TULSA
PHILADELPHIA • SAN DIEGO • ST. PETERSBURG

ROSKOTE

Royston Laboratories, Inc. MLc-1
Pittsburgh 38, Pa.

Please send me complete information about the economies and application of:
☐ Roskote ☐ Roskoter ☐ Line travel equipment

Name.....

Company.....

Address.....

City.....Zone.....State.....

ADVANCE PROGRAM
17th Annual NACE Conference
March 13-17, Buffalo, N.Y.

Pipeline General

Thursday, March 16, 2 pm

Chairmen: Carlton L. Goodwin, Portland Pipeline Corp., Portland, Me., and E. L. Karraker, Shell Oil Co., Indianapolis, Ind.

Theory and Application of Deep Ground Beds, by J. F. Tatum, Willmut Gas and Oil Co., Hattiesburg, Miss.
Design of uncased type deep well anode bed is described in detail with formula developed to determine economical length of anode material. Also discuss resistance of anodes to earth and factors affecting these resistances. Types of backfill with different methods of application and their results are shown. Interference is explained on basis of potential gradients. Efficiency of current use is compared with a surface bed. Cost factors of a deep ground bed installation are discussed in detail and compared to those of surface type ground bed.

Performance of 335 Miles of Asphalt Mastic Coated Pipe, by Gerald J. Paisley, Magnolia Pipe Line Co., Wichita, Kan.
Follow-up report on that given by Donald E. Miltner of Socony-Vacuum Oil Company (see Corrosion, Vol. 9, Page 210, July, 1953) on 335 miles of continuous asphalt mastic coated pipe laid in 1941 as examined by leakage conductance coating survey. Outlines method of test, describes test results, details typical coating failures and discusses coating behavior with particular reference to prolonged effect of cathodic protection.

Ten Years Underground—Microcrystalline Wax Pipe Coating Overwrapped With Vinylidene Chloride Copolymer Plastic Wrapper, by A. A. Brouwer, Dow Chemical Co., Midland, Mich.
A 12-inch pipeline 26 miles long constructed in central Michigan in 1950-51 and cathodically protected with 116 magnesium anodes shows no significant change in pipe-soil potential during 10 years. Soil resistivity over most of route varies from 2000 to 6000 ohm/cm. Line was excavated recently at six scattered locations and samples of wax, plastic wrapper and soil at pipe depth obtained. Magnesium anodes also were removed for examination. Data are given on comparative physical property evaluation of coating and wrapper, estimated current requirements for protection, pipe-to-soil potential profiles and microbial aspects of soil.

Typical Gas Distribution Corrosion Control Procedure Manual, by Joseph Frink, Corrosion Control Service, Coral Gables, Fla.
Presents typical procedure to inform employees on necessity for and application of corrosion control for gas distribution properties. Describes responsibilities for each individual beginning with chief engineer through coating applicator and backfill operation in the field. Typical anode installation drawings are given with methods of installing and testing insulating flanges and couplings. Information intended as guide for corrosion engineers to set up procedure manuals.

High Purity Water

Thursday, March 16, 2 pm

Chairmen: W. K. Boyd, Battelle Memorial Institute, Columbus, Ohio, and A. L. Medin, United States Steel Corp., Monroeville, Pa.

Shot Peening for Protection Against Stress Corrosion Cracking, by Henry Suss, General Electric Co., Schenectady, N. Y.
When properly incorporated into a specific product design and effected by properly designed and controlled process, shot peening will protect hardened AISI 410 stainless steel from stress corrosion failure in high purity waters at temperatures to 300 F for a useful finite period at stresses to 60,000 psi and indefinitely at stresses to about 45,000 psi, about one-third of the yield strength. Consideration must be given to effects of environment, anticipated stresses and temperature of application on fadeout of surface residual layer. Basic data developed could be applicable to other susceptible alloys as means for protection against stress corrosion attack.

Corrosion of Inconel in Primary Coolants of Pressurized Water Reactors, by H. R. Copson, International Nickel Co., Inc., Bayonne, N. J., and W. E. Berry, Battelle Memorial Institute, Columbus, Ohio
Tests were conducted in lithium hydroxide treated water (pH 10) under simulated static control-rod environmental conditions at 300 F, in same water under dynamic bulk-coolant flow conditions at 550 F and in static ammoniated water (pH 9.5) at 550 F. Inconel alloy was coupled to itself and to several stainless steels, nickel-base alloys and other materials. Corrosion behavior of Inconel alloy weld overlays on mild steel also was studied. Results of 2000-hour tests showed no acceleration of attack on any dissimilar metal alloys in galvanic couples. Different heat treatments, cold reduction, or variation in alloy composition had no adverse effect. Weld metal overlays also were resistant to primary coolant waters.

Marine

Friday, March 17, 9 am

Chairmen: W. L. Miller, New York Naval Shipyard, Lynbrook, N. Y., and F. W. Fink, Battelle Memorial Institute, Columbus, Ohio

Corrosion Measuring Sensors for Ships, by David Roller and Willard R. Scott, Jr., Magna Products, Inc., Anaheim, Cal., and Herman S. Preiser and Frank E. Cook, Department of Navy, Bureau of Ships, Washington, D. C.
Describes design, fabrication and testing of four types of corrosion measuring probes for use on maritime vessels. Probes use electrical resistance method for continuous monitoring amount and rate of corrosion of various critical components during operation of ship. One probe has been designed for monitoring corrosion on coated or uncoated ship hulls to determine effectiveness of cathodic protection techniques. Another for measuring condenser tube inlet corrosion. A third for measuring corrosion in tanks and pipe lines. Laboratory and service testing of these probes has been undertaken. Test results and effectiveness of these probes is discussed.

Tanker Corrosion and Use of Galvanic Anodes, by E. E. Nelson, Socony Mobil Oil Co., Paulsboro, N. J.
From over a thousand tank inspections, types of tanker corrosion can be classified under four operation conditions as to whether cargo is principally a petroleum material of low or high viscosity. Some discussion given on mechanism of tanker corrosion. Experience with galvanic anodes indicates substantial saving in ballast tanks and less corrosion in other tanks because of shortened ballast time. Results show benefits from fresh water rinsing.

Cavitation Erosion and Behavior of Materials, by J. Z. Lichtman, D. H. Kallas and C. K. Chatten, New York Naval Shipyard, Brooklyn, N. Y., and Cdr. E. P. Cochran, Jr., Office of Naval Research, Washington, D. C.
To clarify mechanism of cavitation erosion of guiding surface moving relative to a fluid, studies were made using high speed cinematography and a rotating disk cavitation apparatus. Photographs were taken at 7000 pps, using disk shaft speeds from 3200 to 1610 rpm, corresponding to relative linear velocities from 150 to 75 fps. Cavitation clouds trailing from disk holes formed and collapsed cyclically at rate from 2300 cps to 3200 rpm to 1400 cps at 1610 rpm. Cavitation erosion resistance and related properties of several metallic and plastic structural materials and metallic and polymeric coatings also were studied to develop materials having optimum cavitation erosion resistance. These properties and their significance to cavitation erosion resistance are discussed. Also gives details on materials and coatings which show promise.

New Corrosion Demands for Sea-Going Metals, by Frederick W. Fink, Battelle Memorial Institute, Columbus, Ohio
New concepts in hydrofoil vessels, sea-water conversion units, off-shore stations, deep diving submarines and associated marine developments are requiring metals with improved mechanical and corrosion resistant properties. Summarizes present status of the art and research in progress to achieve the new metals of handling sea water at high temperatures, high velocity or at high pressure.

Cathodic Protection

Session Two, Friday, March 17, 9 am

Electrochemical Theory of Cavitation Damage, by H. S. Preiser, Navy Department, Bureau of Ships, Washington, D. C.
Reviews literature on cavitation damage and attempts to arrive at a unified explanation of mechanism of cavitation damage. Prevailing mechanical theory of cavitation damage is modified by electrochemical mechanism which attempts to correlate behavior of materials under varying cavitation intensities and in various fluid environments. Some experiments are described on role of cathodic protection in influencing damage rate. Recommendations for future research are given.

High Density Polyolefin for Cathodic Protection Cable Insulation, by L. A. Hugo and C. W. Blackburn, Phillips Petroleum Co., Bartlesville, Okla. and R. F. Craig and T. V. Gay, Phillips Chemical Co., Bartlesville, Okla.
Performance data from two years' service are given on use of cathodic protection cable insulated with high density polyolefin. Properties, weight and cost are compared with other commonly used cathodic protection cable insulating materials. Techniques for handling and splicing this new type cable are described.

Chemical Industry

Session Three, Friday, March 17, 9 am

Method for Prevention of Hydrogen Embrittlement of Tantalum in Aqueous Media, by Claude R. Bishop, Union Carbide Metals Co., Niagara Falls, N. Y., and Milton Stern, Linde Company, Indianapolis, Ind.
Results of laboratory experiments are described in which tantalum was protected successfully from embrittlement in highly corrosive environments at different temperatures or under conditions of cathodic charging. Technique is simple and should find application by expanding the range of environments which can be served by tantalum.

Generalized Description of Metallic Passivity, by N. D. Greene, Rensselaer Polytechnic Institute, Troy, N. Y.
Described metallic passivity with concept of mixed potentials and results of potentiostatic polarization measurements. Active-passive behaviors of iron, chromium, titanium and stainless steels are compared with their specific corrosion resistant properties. These results are applied to engineering problems of alloy selection and corrosion prevention.

1961 Corrosion Show Exhibitors

Booth No.

1—Fibercast Company
2, 3—Kendall Company
4, 5, 6—Shell Oil Company
7, 8—Amercoat Corporation
9, 10—Dow Chemical Company
11, 12—du Verre, Inc.
13—Consolidated Mining & Smelting Co., Ltd.
14, 15—Duriron Co., Inc.
16, 17—Metallizing Service Contractors
18, 19—Minnesota Mining and Manufacturing Co.
20—Crucible Steel Co. of America
21—A. M. Byers Company
22—Knapp Mills, Inc.
24, 25—Carboline Company
26, 27—M. C. Miller Company
28, 29, 30—Owens-Corning Fiberglas Corp.
31, 32, 33—Koppers Company, Inc.

Booth No.

34, 35—International Nickel Co., Inc.
36—Tinker & Rasor
37—Central Plastics Company
38, 39—Pfaudler-Permutit, Inc.
40—National Carbon Company
41—Clementina Limited
42—Alloy Steel Products Company
43, 44—Cathodic Protection Service
45—Coast Paint & Lacquer Company
46—Goulds Pumps, Inc.
47—Enco Sales, Inc.
48—Minnesota Mining & Manufacturing Co.
49—DeVilbiss Company
50—Standard Magnesium Corp.
51, 52—Seamless Rubber Company

Booth No.

54—Harco Corporation
55—Truscon Laboratories
56, 57—U. S. Stoneware
58—Royston Laboratories, Inc.
59, 60—Aluminum Company of America
61, 62 — Johns-Manville Sales Corp.
63, 64, 65—Shell Chemical Company
66—Centriline Corporation
67—Delaware Barrel & Drum Company, Inc.
68—Dia-Plug Division, Cryogenics Corp.
69—Garlock, Inc.
70, 71—Glidden Company
72—Radio Receptor Co., Inc.
73—Dearborn Chemical Company
74—American Hot Dip Galvanizers Assoc., Inc.

Booth No.

75—Heil Process Equipment Corp.
76—Wheelabrator Corporation
77—Reilly Tar & Chemical Corp.
78—H. C. Price Company
79, 80—Metal-Cladding, Inc.
81—Chas. Pfizer and Company, Inc.
82—Pittsburgh Chemical Company
84, 85—American Smelting & Refining Co.
87—Lincoln Engineering Company
89—E. I. du Pont.
90—Tapecoat Company
91—John L. Doré Company
92—Pittsburgh Corning Corp
93—Carpenter Steel Company
94, 95—Resistoflex Corp.
96, 97—Hercules Powder Company
100, 101—Gray Co., Inc.

Partial List of Products at 1961 Corrosion Show

A

Aluminum pipe 59, 60
ANODES
Galvanic 84, 85
Graphite 40, 43, 44
High silicon cast iron..43, 44
Lead 13
Magnesium 43, 44, 50
Magnesium, extruded ribbon 50
Magnesium, hot water heaters..... 50
Magnesium, tank 50
Splicing kits 48
Titanium 43, 44
Zinc 13, 43, 44

B

Bellows, fluorocarbon 91
Blast cleaning equipment..41, 76
Building materials 59, 60
Brick, acid resistant.....56, 57

C

CATHODIC PROTECTION
Cable 43, 44
Cable connectors 43, 44
Design services 54
Installation services..... 54
Instruments 36, 43, 44
Materials 43, 44, 84, 85
Rectifiers 43, 44, 72
Systems 43, 44
Cements, acid proof 7, 8
Ceramics, chemical 56, 57
Chemical cleaning, alkaline.. 81
Chemical cleaning, acid .. 81
Cleaning equipment 100, 101
COATINGS
Asphalt mastic 78
Chlorinated polyether ..96, 97
Coal tar 77
Coal tar emulsion..31, 32, 33
Coal tar enamel, pipelines 31, 32, 33
Cold applied 77
Cold applied coal tar 31, 32, 33
Cold applied primers.31, 32, 33
Epoxy 56, 57, 73
Epoxy tar 24, 25
Exterior concrete pipe .. 78
Enamels, hot applied ... 77
Fluidized bed process ..96, 97
Floors 55
Industrial 7, 8, 73, 79, 80
Inorganic zinc 24, 25
Organic 96, 97
Maintenance 58
Masonry 55

COATINGS (Cont'd)
Mastic, cold applied 58
Meters 58
Metal pipe 96, 97
Modified PVC 56, 57
Phenolic 56, 57, 24, 25
Pipelines 73
Pipeline primer 31, 32, 33
Plastisol 58
Primers 58
Polyurethanes 24, 25
Vinyls 24, 25
Containers, shipping, polyethylene 67
Corrosion engineering services 54

D

Ducts and stacks, plastic .. 75
Dust and fume control equipment 76

E

Expansion joints, fluorocarbon lined 91

F

Fans, plastic coated 75
FITTINGS
Pipe, fluorocarbon 94, 95
Pipe, fluorocarbon lined... 91
Plastic 67

G

GASKETS
Asbestos 69
Fluorocarbon 69, 91
Spiral wound 69

H

HEAT EXCHANGERS
Graphite 40
Tubes 59, 60
Holiday detectors 36

I

INSTRUMENTS
Cathodic protection .26, 43, 44
Holiday detectors 36
Corrosion tester, high temperature 73
INSULATING
Bushings 37
Couplings 43, 44
Meter connections 37
Unions 37, 47
INSULATORS
Casing 43, 44
Flanges 37, 43, 44

L

Linings 79, 80
Linings, fluorocarbon and chlorinated polyether 69

P

Packing, fluorocarbon ..69, 91
PIPE
Aluminum 59, 60
Asbestos cement 61, 62
Asbestos reinforced resin 61, 62
Glass reinforced polyester 79, 80
Lining, cement mortar .. 66
Plastic 7, 8, 56, 57
Polyvinyl chloride 21
Putty 48
Stainless steel 93
Steel, fluorocarbon lined 94, 95
Wrought iron 21
Pipe cleaning services 66
PIPELINE
Enamels 31, 32, 33
Glass wraps 58
Inspection surveys 66
Joint sealing and repair .. 66
Lining, epoxy mortar 66
Primers 3, 32, 33
Piston rings, fluorocarbon .. 91
PLASTICS
Ducts and stacks 75
Ducts, glass reinforced polyester 79, 80
Epoxy resin 48
Fittings, polyethylene 67
Fluorocarbon 69, 91
Hoods 75
Pavement inserts 37
Pipe, glass reinforced polyester 79, 80
Process equipment 11, 12
Sheet 7, 8
Shipping containers, polyethylene 67
Spigots, polyethylene 67
Tanks, storage, polyethylene 67
Tanks, glass reinforced polyester 79, 80
Tank covers 75
PROCESS EQUIPMENT
Fume scrubber, plastic .. 75
Glass reinforced polyester 79, 80
Graphite, heating and cooling 75
Lined tanks 96, 97
Reinforced fiberglass ..56, 57
Reinforced plastic 11, 12
Valves, pumps, meters .96, 97
Vessels, plastic coated .96, 97
Pumps, graphite 40

R

Rectifiers, cathodic protection 43, 44, 72
Roof ventilator, plastic and plastic lined steel 75

S

SANDBLASTING
Equipment 41
Helmets 41
Hose and couplings 41
Nozzles 41
Suction guns 41
Valves, remote control .. 41
Seals, mechanical with fluorocarbon bellows 69
SPRAYING EQUIPMENT
Airless-hydraulic units ... 87
Catalyst type 49
Catalyst pump 100, 101
Compressors 49
Guns 49
Hot application 49
Hose 49
Paint pumps 100, 101
Paint tanks 49
Surveys, gas leakage 37

T

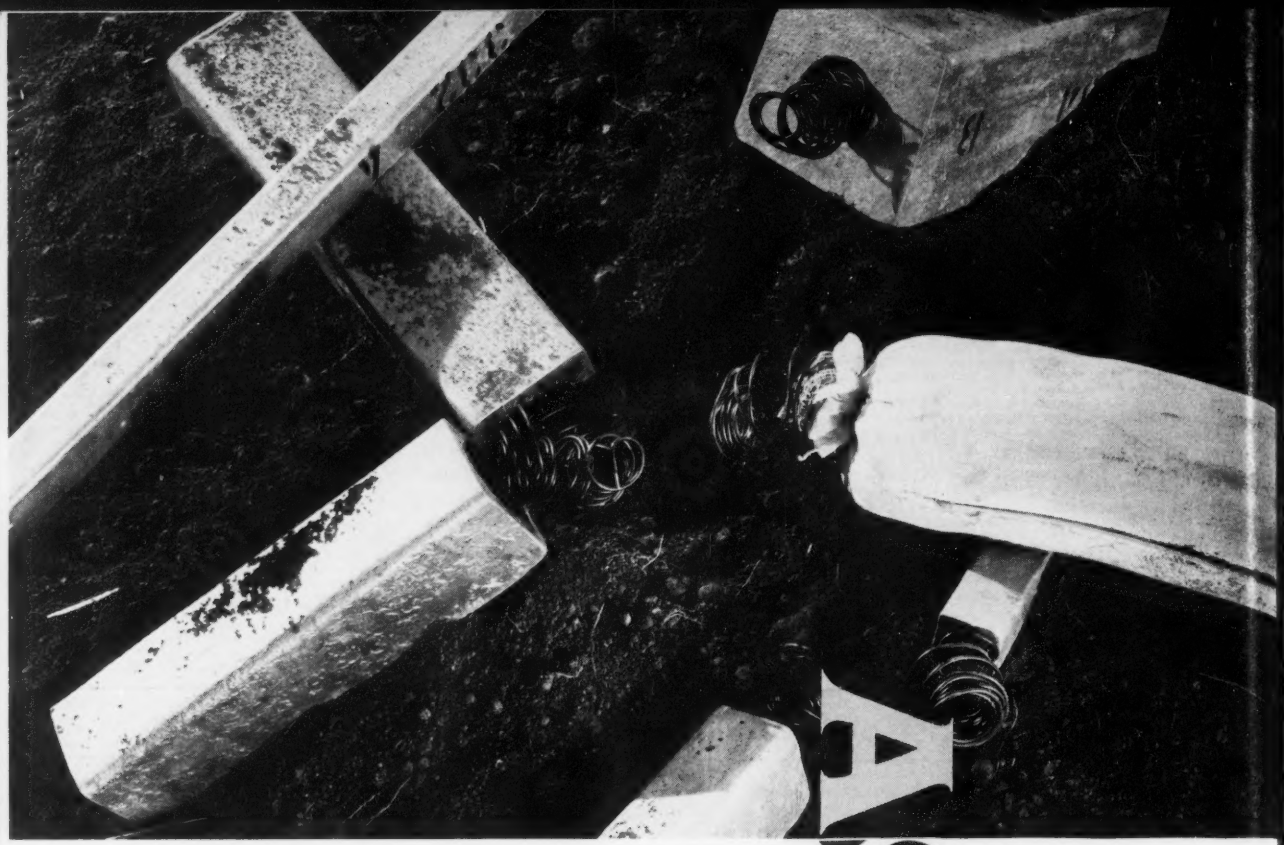
Tank linings, plastic 75
Tank linings 56, 57
TAPES
Application machines ..43, 44
Dry thread sealing 48
Plastic 43, 44, 58, 61, 62
Polyethylene 2, 3
Polyvinyl chloride, pressure sensitive 48
TESTING
Corrosion tester, high temperature 73
Portable water treatment kit 73

V

Valves, graphite 40
Ventilation equipment 75

W

Water treatment equipment . 73
Wrought iron pipe 21



Corrosion control positive:

FEDERATED GALVANIC ANODES

and other non-ferrous protective materials

Federated galvanic anodes, specially designed to protect pipelines and other buried structures, are just one of the wide range of Federated materials to control corrosion. Federated's Corrosion Advisory Service can recommend the best for you . . . magnesium or zinc anodes; lead sheet, pipe, and fittings; zinc and zinc alloys for galvanizing; copper and aluminum alloys; and plating materials that include nickel, copper, lead, cadmium, zinc and silver anodes, nickel salts and addition agents for plating baths. For complete data, write or call—Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, N. Y. or a nearby Federated sales office.

ASARCO

AMERICAN SMELTING AND REFINING COMPANY

FEDERATED METALS DIVISIO

Where to call for information:

ALTON, ILLINOIS
Alton: Howard 5-2511
St. Louis: Jackson 4-4040

BALTIMORE, MARYLAND
Orleans 5-2400

BIRMINGHAM, ALA.
Fairfax 2-1802

BOSTON 16, MASS.
Liberty 2-0797

CHICAGO, ILL. (WHITING)
Chicago: Essex 5-5000
Whiting: Whiting 826

CINCINNATI, OHIO
Cherry 1-1678

CLEVELAND, OHIO
Prospect 1-2175

DALLAS, TEXAS
Adams 5-5034

DETROIT 2, MICHIGAN
Trinity 1-5040

EL PASO, TEXAS
(Asarco Mercantile Co.)
3-1852

HOUSTON 29, TEXAS
Orchard 4-7611

LOS ANGELES 23, CALIF
Angelus 8-4291

MILWAUKEE 10, WIS.
Hilltop 5-7430

MINNEAPOLIS, MINN.
Tuxedo 1-4109

NEWARK, NEW JERSEY
Newark: Mitchell 3-0500
New York: Digby 4-9460

PHILADELPHIA 3, PENNA.
Locust 7-5129

PITTSBURGH 24, PENNA.
Museum 2-2410

PORTLAND 9, OREGON
Capitol 7-1404

ROCHESTER 4, NEW YORK
Locust 5250

ST. LOUIS, MISSOURI
Jackson 4-4040

SALT LAKE CITY 1, UTAH
Empire 4-3601

SAN FRANCISCO 24, CALIF.
Atwater 2-3340

SEATTLE 4, WASHINGTON
Main 3-7160

WHITING, IND. (CHICAGO)
Whiting: Whiting 826
Chicago: Essex 5-5000

IN CANADA: Federated Metals Canada, Ltd.
Toronto, Ont., 1110 Birchmount Rd., Scarborough, Phone: Plymouth 73246

Montreal, P.Q., 1400 Norman St., Lachine, Phone: Melrose 7-3591

CORROSION ABSTRACTS

INDEX TO CORROSION ABSTRACTS

Vol. 17 January, 1961 No. 1

1. GENERAL
- 1.2 Importance 57
- 1.6 Books 58
- 1.7 Organized Studies of Corrosion 59

4. CORROSIVE ENVIRONMENTS
- 4.2 Atmospheric 59
- 4.3 Chemicals, Inorganic 60
- 4.5 Soil 60
- 4.6 Water and Steam 60
- 4.7 Molten Metals and Fused Compounds 61

5. PREVENTIVE MEASURES
- 5.2 Cathodic Protection 61
- 5.3 Metallic Coatings 62
- 5.4 Non-Metallic Coatings and Paints 62
- 5.8 Inhibitors and Passivators 63
- 5.9 Surface Treatment 63

6. MATERIALS OF CONSTRUCTION
- 6.3 Non-Ferrous Metals and Alloys—Heavy 63
- 6.4 Non-Ferrous Metals and Alloys—Light 65
- 6.6 Non-Metallic Materials 66

7. EQUIPMENT
- 7.2 Valves, Pipes and Meters 68
- 7.5 Containers 68
- 7.6 Unit Process Equipment 68

8. INDUSTRIES
- 8.4 Group 4 69
- 8.9 Group 9 71

1. GENERAL

1.2 Importance

1.2.5, 3.8.4, 3.5.9

Investigation of Ignition Temperatures of Solid Metals. W. C. Reynolds. Stanford Univ., Calif. U. S. National Aeronautics and Space Administration, Technical Note D-182, October, 1959, 71 pp. Available from Office of Technical Services, Washington, D. C.

The ignition temperature of a solid metal is related through a thermal definition of ignition to the rate of oxidation and to the radiation and convection heat-transfer parameters. The mechanisms of oxidation are reviewed, and the factors which influence ignition temperatures are discussed. Reasonable agreement between theoretical and experimental ignition temperatures is demonstrated. Experimental ignition temperatures for several metals are presented. (auth)—NSA. 19428

1.2.5

Metal Fire and Explosion Research. J. Glenn Schnizlein. Argonne National Lab. pp. 40-43 of Proceedings of the 1958 Atomic Energy Commission and Contractor Safety and Fire Protection Conference, Held at Atomic Energy Commission Headquarters Building, Germantown, Maryland, June 24-25, 1958, TID-7569 (pp. 40-43). Available from Office of Technical Serivces, Washington 25, D. C.

A discussion is presented of a program directed toward determining the factors involved in the susceptibility of ignition of uranium, zirconium, thorium and plutonium.—NSA. 19024

1.2.5, 3.8.4, 8.4.5, 6.3.17, 6.3.20

Ignition Behavior and Kinetics of Oxidation of the Reactor Metals, Uranium, Zirconium, Plutonium and Thorium, and Binary Alloys of Each. A Status Report. J. G. Schnizlein, P. J. Pizzolato, H. A. Porte, J. D. Bingle, D. F. Fischer, L. W. Mishler and R. C. Vogel. Argonne National Lab. U. S. Atomic Energy Commission Pubn., ANL-5974, April, 1959, 207 pp. Available from Office of Technical Services, Washington, D. C.

The importance of prevention of fires and explosions involving uranium, zirconium, plutonium and thorium, which are of particular interest to the nuclear energy program, made imperative the study of their ignition behavior and oxidation kinetics. Methods of measurements of ignition characteristics of uranium and zirconium were developed and used to determine the effects of variables, such as surface preparation, metallurgical history, specific area (sample size) additives to the metal, oxygen content and presence of moisture in the oxidizing gas. The study of ignition characteristics was supported by study of the effects of similar variables on the kinetics of oxidation of uranium and zirconium and binary alloys of each. The oxidation of uranium always proceeded in two linear stages over the temperature range of 125 to 295 C at

Abstracts in This Section are selected from among those supplied to subscribers to the NACE Abstract Punch Card Service. Persons who are interested in reviewing all available abstracts should write to NACE for information on this service.

PHOTOPRINTS and/or MICROFILM COPIES

of Technical Articles Abstracted in

Corrosion Abstracts

May Be Obtained From

ENGINEERING SOCIETIES LIBRARY, 29 West 39th Street, New York 18, N. Y.

CARNEGIE LIBRARY OF PITTSBURGH, 4400 Forbes St., Pittsburgh 13, Pa.

NEW YORK PUBLIC LIBRARY, New York City.

U. S. DEPT. OF AGRICULTURE LIBRARY, Office of Librarian, Washington, D. C. (Special forms must be secured).

LIBRARY OF CONGRESS, Washington, D. C.

JOHN CREAR LIBRARY, 86 East Randolph St., Chicago 1, Ill.

Persons who wish to secure copies of articles when original sources are unavailable, may apply directly to any of the above for copies. Full reference information should accompany request. The National Association of Corrosion Engineers offers no warranty of any nature concerning these sources, and publishes the names for information only.

NACE will NOT accept orders for photoprint or microfilm copies of material not published by the association.

CODE OF AGENCIES SUPPLYING CORROSION ABSTRACTS

Neither NACE nor the sources listed below furnish reprint copies.

ATS—Associated Technical Service Abstracts, Associated Technical Services, P. O. Box 271, East Orange, New Jersey.

AWWA—Journal, American Water Works Association, Amer. Water Works Assoc., Inc., 2 Park Ave., New York 16, New York.

BL—Current Technical Literature, Bell Telephone Laboratories, 463 West St., New York 14, New York.

BTR—Battellee Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

CO—Centre d'Information du Cobalt, 35 Rue des Colonies, Brussels 1, Belgium.

EL—Electroplating and Metal Finishing, 85 Udney Park Road, Teddington, Middlesex, England.

GRR—U. S. Government Research Reports, Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

HB—Translations, Henry Brutcher, P. O. Box 157, Altadena, California.

IIM—Transactions of The Indian Institute of Metals, 31 Chowringhee Rd., Calcutta 16, India.

INCO—The International Nickel Co., Inc., 67 Wall Street, New York 5, New York.

JSPS—Japan Society for the Promotion of Science, Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1 Chome Nakameguro, Meguro-Ku, Tokyo, Japan.

LD—Larissa Domnikov, 8101 Creighton Ave., Los Angeles 45, Cal.

LMB—Light Metals Bulletin, Intelligence Dept., British Aluminium Co., Ltd., Norfolk House, St. James' Square, London, SW 1, England.

MA—Metallurgical Abstracts, Institute of Metals, 17 Belgrave Square, London SW 1, England.

NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tennessee.

OTS—Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

PDA—Prevention of Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

PI—Pergamon Institute, 1404 New York Ave., N. W., Washington 5, D. C.; Oxford and London, England.

PMR—Platinum Metals Review, Johnson, Matthey and Co., Ltd., 73-83 Hatton Garden, London, E.C. 1, England.

RIM—International Union of Testing and Research Laboratories for Materials and Structures, RILEM Bulletin, 12, Rue Brancion, Paris XV, France.

RML—Review of Metal Literature, American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Assoc. of British Paint, Colour and Varnish Manufacturers, Paint Research Station, Waldegrave Rd., Teddington, Middiesex, England.

SE—Stahl und Eisen, Verlag Stahleisen, m.b.H., Breite Strasse 27 (Schliessfach 2590), Dusseldorf, Germany.

TIME—Transactions of The Institute of Marine Engineers, The Memorial Bldg., 76 Mark Lane, London EC 3, England.

TT—Technical Translations, Office of Technical Services, U. S. Department of Commerce, Washington 25, D.C.

ZDA—ZDA Abstracts, Zinc Development Association, 34 Berkeley Square, London W 1, England.

pressures of 20, 50, 200 and 800 mm. of oxygen. The temperature dependences of both stages indicate an activation energy dependent on pressure. The presence of ten additive elements in uranium metal caused only very small effects on the oxidation. The oxidation of zirconium was independent of pressure and proceeded according to a cubic rate law over the temperature range from 400 to 900 C, with an activation energy of 42.7 kcal/mole. For those additives soluble in zirconium at 700 C, the effects on the initial cubic rate law for oxidation are explained in terms of valency according to the Wagner-Hauffe Theory. For those additives insoluble in alpha zirconium, no single theory is felt to be adequate. The breakaway phenomena observed for many of the 20 alloys is explained in terms of a 15 percent deviation of the additive ionic radius from the ionic radius of zirconium. Surveys of the literature on the oxidation of plutonium and thorium are presented in preapration for the study of their behavior. (auth)—NSA. 19481

1.6 Books

1.6, 8.7.2, 3.2.2

Corrosion of Chemical Apparatus. (In Russian.) G. L. Svartz and M. M. Kristal. Book, 256 pp., 1958. Translation published in 1959. Consultants Bureau, Inc., 227 West 17th St., New York 11, N. Y.; Chapman & Hall, Ltd., London, England.

This monograph on the corrosion and stress corrosion of metals and alloys used in chemical plant construction was originally published in Russian in 1958 by the State Scientific Technical Press for Machine Construction Literature, Moscow. It is designed for all persons concerned with chemical plant corrosion problems.

The authors first consider the theoretical factors involved in corrosion cracking and then consider the corrosion cracking of carbon and low alloy steels. The section on stainless steels covers chromium and chromium nickel steels. The portions dealing with chromium-nickel austenitic steels under static stress include such topics as effect on structure of steel, effect of chemical composition of steel, heat treatment, stress effect of the nature of the medium with respect to its contents and their concentrations.

The section on non-ferrous metals and alloys covers aluminum, copper and copper alloys, nickel and nickel alloys, magnesium, lead, titanium and others.

The section on preventive measures includes material selection, construction methods, techniques, stress relief, electrochemical measures, with special attention to protection against intercrystalline corrosion. The final section is on testing methods.

Of the 219 references only a small percentage are to material published outside of the Soviet orbit. The book is thoroughly illustrated and contains many tables and graphed data. 19609

1.6, 8.4.5

Reactor Core Materials. Technical Progress Reviews. Battelle Memorial Inst., Vol. 2, No. 3, 1959, 58 pp. Available from U. S. Government Printing Office, Washington, D. C.

This volume is divided into five sections. Section 1 is devoted to fuels and fertile materials and includes unalloyed uranium, alpha-uranium alloys, gamma-phase alloys, epsilon-phase alloys, dilute uranium alloys, plutonium and alloys, thorium and alloys, dispersion fuel materials, refractory fuel and fertile materials, diffusion studies, mechanism of corrosion of fuel alloys and basic studies of radiation effects in fuel materials. The second section on moderator materials includes graphite, beryllium metal and alloys, beryllium compounds and solid hydrides. The third section discusses nuclear poisons. The fourth section is devoted to cladding and structural materials and includes corrosion radiation effects in nonfuel materials, selected metallurgical aspects of cladding and structural materials, and selected mechanical properties of cladding and structural materials. The last section on special fabrication techniques includes melting, casting, heat treatment, hot working, cladding, welding, brazing and nondestructive testing.—NSA. 19687

1.6

Corrosion and Oxidation of Metals. Ulick R. Evans. Book, May 12, 1960, 1094 pp. St. Martin's Press, Inc., 175 Fifth Ave., New York 10, N. Y.

A completely rewritten and revised general discussion of all aspects of corrosion and corrosion control. It is a counterpart of the same author's book, "Metallic Corrosion, Passivity and Protection" first issued in 1937 and revised in 1946. Dr. Evans, a world renowned worker in corrosion, received the 1948 Willis Rodney Whitney Award of the National Association of Corrosion Engineers in 1948 in recognition of his achievements in corrosion science.

Some idea of the magnitude of the work involved in the book may be estimated from the author index comprising about 3000 names. Dr. Evans has injected references to articles bearing on his subjects in the text in footnotes and at chapter endings, a practice which gives his readers ample means of pursuing their interests to the fullest extent permitted by published data.

Book is organized so that the persons of diverse interests and attainments known to be interested in and concerned with corrosion control will find ample material to satisfy their demands for information. While no special effort is made to over-simplify explanations, the author recognizes that some may not have achieved competence in some of the scientific disciplines which will permit them to pursue explanations relying exclusively on mathematics, or electrochemical theory, for example. Nevertheless, these aspects of the corrosion story are neither over-looked nor slighted. The first 18 chapters have been left substantially free of equations.

Author recognizes the fact that few can be expected to read the whole book, and surmises that many will read thoroughly those portions of pressing immediate interest and then put it aside for reference use later.

While a 16-page subject index may be somewhat abbreviated for a book of this size, the organization of the book is such that most users probably will be able to locate information without difficulty. The author's style is lucid and brief without being terse. The large number of illustrations also adds to ready understanding. Each chapter opens with a synopsis which generalizes on the material covered. 19757

1.6, 5.9.1, 6.4.2

Surface Treatment and Finishing of Aluminium and Its Alloys. Second Edition. S. Wernick and R. Pinner. Book, 1959, 607 pp. Robert Draper Ltd., 85 Udney Park Rd., Teddington, Middlesex, England.

Second edition of an encyclopedic work. Data are extensively presented in 204 figures and 120 tables. Each section is accompanied by a list of references.

Chapters cover corrosion and protection of aluminum and its alloys, mechanical surface treatments and finishes, electrolytic and chemical polishing processes, chemical cleaning and anodic etching, chemical conversion coatings, anodizing of aluminum, general notes and theory, decorative and protective anodizing, hard anodizing, coloring anodic oxide coatings, sealing anodic outside coatings, physical and chemical properties of anodic coatings, electrodeposition on aluminum (four chapters); organic finishing, vitreous enameling, metal spraying.

Major British and U. S. aluminum alloys are described in an appendix. There is an extensive subject index 18553

1.6, 4.2.5, 4.6.11

Marine Corrosion Handbook. T. Howard Rogers. Book, Jan., 1960, 297 pp. McGraw-Hill Book Company, Inc., 330 West 42nd St., New York 36, N.Y.

A handbook designed for the use of operating engineers and draughtsmen who are not necessarily conversant with corrosion theory. The author, formerly Corrosion Investigator, British Non-Ferrous Metals Research Association, and now Officer-in-Charge, Naval Research Dockyard, Laboratory, Halifax, notes in a perface that his principal books of reference number six of which three were published in England.

Material is arranged in alphabetical order beginning with Admiralty Brass and ending with zinc chromate. In between are hundreds of items, considerer briefly in clear prose. There are numerous illustrations and diagrams, a glossary of corrosion terms (none from the NACE Intersociety Corrosion Committee's compilation) and an alphabetical subject index.

Subject matter, designed principally for the information of Canadian Royal Navy personnel, is oriented exclusively toward the salt water marine environment. 19431

1.6, 3.7.3

Soldering Manual. Prepared by American Welding Society Committee on Brazing and Soldering. F. W. Hussey, Chairman. Book, 170 pp., 1959. Available from: American Welding Society, 33 West 39th Street, New York 18, N. Y.

Principles of sound soldering practice are presented. A table gives relative solderability of metals, alloys and coatings, including flux requirements.

Chapters cover principles, solders, fluxes, joint design, precleaning and surface preparation, equipment, processes and procedures; flux residue treatment, inspection and testing.

Copper and copper alloys, steel, coated steels, stainless steels, nickel and high-nickel alloys, lead and lead alloys, aluminum and aluminum alloys, tin, cast irons, precious metal coatings, primed circuits and safety. There are numerous illustrations and tables. There is a 16 page alphabetical subject index. 18481

1.6, 5.2.1

Cathodic Protection. Lindsay M. Applegate. Book, Jan. 4, 1960, 229 pp. McGraw-Hill Book Company, Inc., 330 West 42nd St., New York 36, N. Y.

Developed from material prepared originally for corrosion and cathodic protection instruction of military personnel. The "do-it-yourself" approach is emphasized. Recognized published authorities have been used as sources supplemented by practical examples accumulated by the author during his work from Okinawa to North Africa and from Maine to California.

Chapters are headed: Corrosion and cathodic protection, instruments and measurements, surveys and current tests, coatings, anodes; design, construction and maintenance; protection of structures in contact with soil and protection under water and special conditions.

The book is extensively illustrated with diagrams and halftones. There is an alphabetical subject index. 19631

1.6, 5.9.4, 5.9.2

Electropolishing, Anodizing and Electrolytic Pickling of Metals. N. P. Fedot'ev and S. Ya. Grilikhes. Translated from the Russian by A. Behr. Book, February, 1960, 285 pp. Robert Draper Ltd., 85 Udney Park Road, Teddington, Middlesex, England.

Authors exhaustively discuss Russian practice. Revealed are details of many methods which are closely held trade secrets among Western metal finishers. Chapter headings are: Electrolytic pickling of metals, electropolishing of steel, non-ferrous light and precious metals.

Effect of electropolishing on metal properties, practical electropolishing, applications of electropolishing, anodizing aluminum and its alloys, industrial anodizing, applications of anodized aluminum and anodizing of other metals.

There is an appendix consisting of references (almost entirely Russian and Eastern European); tables of surface roughness numbers, designations of Russian aluminum alloys, and an alphabetical subject index. 19751

1.7 Organized Studies of Corrosion

1.7.1, 5.4.8, 4.2.5

Centre for the Study of Marine Corrosion of Metals at Genoa. (In Italian.) G. Balbi. Pitture e Vernici, **14,** No. 12, 987-990 (1958).

Nature of the research undertaken at the Centro di Studio per le Corrosioni Marine dei Metalli at Genoa is described, with photographs of apparatus. Mention is made of marine paints and methods for their evaluation and analysis, study of marine funa and flora and electrochemical studies of corrosion.—RPI. 18692

1.7.1, 5.4.5, 5.9.1

Swedish Contribution for the Protection of Steel Through Painting. Pt. I. Summary of Work Done by the Corrosion Committee During the Past 25 Years. Pt. II. New Standard for Pretreatment and Programme for a Test Series Based on These Standards. P. A. Wallgren. Official Digest, Federation Paint & Varnish Production Clubs, **31,** No. 408, 23-51 (1959) Jan.

Organization of co-operative research schemes for the evaluation of anti-corrosive paints in Sweden is discussed, together with a detailed account of work on surface pretreatment of steel and its effect on coating efficiency. Topics reviewed under the latter subject comprise standardization of degrees of carefulness of surface preparation, nature of pretreatment (principally mechanical and flame cleaning), uniformity of test specimens, types of paint and effect of surface roughness.—RPI. 18610

1.7.3, 3.2.3, 3.8.2, 5.4.5

Corrosion Research in Great Britain and Its Results. W. E. Ballard. J. South African Inst. Min. Met., **59,** No. 12, 623-639 (1959).

Major achievements in corrosion science during the past 20-30 years are listed. Film, electrochemical and painting considerations are among the aspects reviewed.—MA. 19630

1.7.1, 4.2.1, 4.5.1, 6.2.1, 2.3.1

Sixth Report of the Corrosion Committee. Compiled by J. C. Hudson. Book, 1959, 217 pp. The Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1, England.

This report summarizes the work of the British Corrosion Committee since its last report in 1938. Concise information is given on work undertaken by the committee including reports on some of the tests underway and incomplete at the time of the fifth report.

Subjects include: Atmospheric corrosion, corrosion by industrial waters, marine corrosion, soil corrosion, protective coatings, corrosion test procedures.

A section on atmospheric corrosion tests includes the following subjects, general experimental procedure, tests on bare irons and steels, effect of climate, tests on painted irons and steel, paint trials on iron and steel stands and conclusions.

A section on atmospheric corrosion and protection at temperatures up to 300 C covers the following subjects: Experimental program, assessment of corrosion conditions, tests on bare materials, coatings, results of tests on small specimens of sheet, vitreous enamels, patch-painting tests on strip, tests on full-sized sheets, laboratory tests, conclusions.

Section headed marine corrosion service trials covers surface preparation, comparison of compositions, service experience.

Final section covers terms of reference, acknowledgments, a bibliography of the committee's publications and a bibliography of anti-fouling research.

Numerous tables give analyses of materials tested, compositions of coating materials, characteristics of test sites, results of tests of bare and coated materials, effect of millscale, effect of surface condition, results of test on commercial low-alloy steels, analyses of rusts, corrosion-time tests by the decrease-in-breaking load method, analyses of water from deposit gauges comparison of sulfur pollution and corrosion rate, observations of copper-steel specimens, results on zinc specimens, results of tests on painted specimens, lives of painting schemes and others. 18410

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.3, 5.7.7, 5.8.1, 4.3.2

Corrosion Problems Encountered in the Burning of Sulphur-Bearing Fuels in Oil-Fired Burners and Methods of Alleviation. Part 2. H. N. Wigan. Corrosion Prevention and Control, **6,** No. 10, 60, 62, 64 (1959) Oct.

Oxidation of SO_2 and SO_3 and subsequent formation of H_2SO_4 are discussed as chief causes of fouling and corrosion. Chemical control methods reviewed are: neutralizing of SO_3 in flue gases; protection of metal surfaces against effect of corrosive films; and inhibition of SO_3 at source (control of oxidation of SO_2). Use of fuel additives to eliminate sludge formation is discussed; few of these have ability to inhibit SO_3 formation. Description is given of procedure for measuring SO_2 and SO_3 percentages in flue gas (cold or water-cooled probe test). Test is ready method of assessing ability of fuel additive to alleviate fouling, corrosion and acidic smut emission.—INCO. 19597

4.2.1, 2.3.9, 6.3.19, 6.4.2

Study of the Changes in Metal Surfaces Due to Atmospheric Conditions. (In Czech.) A. Hrbek. Hutnické Listy, **14,** No. 2, 111-117 (1959).

Corrosion processes have been followed by the photo-co-electron emission method, based on the emission of electrons from the corroding material during exposure to photons. By measuring the emission from zinc and aluminum after emery polishing, it has been determined that the wavelength limit of the photo-effect for zinc is over 3800 A and is 4000 A for aluminum. Corrosion results in shorter wavelengths. The process of corrosion can be activated by increasing the intensity of specific long-wave irradiation. It has been established that in the case of aluminum there is a spectroscopic sensitivity of 3900 A for atmospheric corrosion.—ZDA. 18437

4.2.2, 3.5.9, 6.2.5, 2.2.2

Intensity of Atmospheric Corrosion of Low Carbon Steel at Below Zero Temperatures. (In Russian.) I. P. Kharlmanov and G. N. Mekhovshchikova. J. Applied Chem., USSR (Zhur. Priklad. Khim.), **32,** No. 2, 443-444 (1959). English Translation of Journal Available

Stop electrolysis by insulating connections with MAYCO Dielectric Fittings or Dielectric Bushings. Bushings are toughest PLASKON nylon with extra-heavy "hex" gripping surface (on most sizes)...withstand pressures to 1000 lbs., temperatures to 300° F. Sizes to 2" for gas, plumbing, heating installations—wherever dissimilar metals are joined. Order from your jobber or write:

MAY PRODUCTS, INC.
GALESBURG, ILLINOIS
Manufacturers of MAYCO Dielectric Fittings — MAYCO Water Softeners

from: Consultants Bureau, Inc., 227 West 17th Street, New York 11, N. Y.

Study of low carbon steel, stored in the open air for about one year, with a winter temperature of —35 C showed that corrosion proceeds slowly at this temperature. Corrosion rate during winter is about three times slower than during spring and summer months. 7 references.—RML. 18466

4.2.3, 6.7.2, 6.6.6

Summary of Third HEF Combustion Product Corrosion Working Group Meeting. James R. Myers. December 29, 1958, 70 pp. U. S. Wright Air Development Center. Project No. 3048, WCLT-TM-58-125. Available from U. S. Wright Air Development Center, Materials Lab., Wright-Patterson Air Force Base, Ohio.

Static and dynamic test programs for the evaluation of selected high-temperature alloys, cermets and ceramics with respect to their corrosion resistance to simulated boron fuel combustion products are presented.—NSA. 18873

4.2.7, 5.4.5, 3.4.9

How Paints Stand Up to Tropical Climates. Pt. I. P. Whiteley. Paint Manuf., **29**, No. 3, 87-90 (1959) Mar.

States that conditions of radiation and moisture are more severe in tropical climates than in temperate, as may be the effects of marine salt spray also, High humidity promotes the growth of molds and algae. Galvanized iron roofs are often used, and often neglected. The author goes on to compare the merits of various painting schemes. When using calcium plumbate primers for painting zinc, he recommends thorough degreasing, either with thinners or a strong solution of household detergent.—ZDA. 18630

4.3 Chemicals, Inorganic

4.3.2,3.5.9,6.2.5

The Corrosion Resistance of Several Alloys in an HF-H_2O Atmosphere at High Temperatures. C. F. Ritchie and E. K. Teter. Mallinckrodt Chemical Works. U. S. Atomic Energy Commission Pubn., NYO-1330, Jan. 22, 1952 (Declassified June 19, 1959), 15 pp. Available from Office of Technical Services, Washington 25, D. C.

Tests indicate that of the various alloys tested for corrosion resistance when exposed to an HF-H_2O atmosphere at 1070 F, the Cr-Ni alloys, as a group, give the best corrosion resistance where strength at high temperature is desired. Other alloys have given excellent results but the lack of strength at the higher temperature or cost, is against their use in production equipment. (auth)—NSA. 19435

4.3.3, 4.2.3

Accelerated High-Temperature Oxidation Due to Vanadium Pentoxide. Pt. II & III. K. Sachs. Metallurgia, **57**, Nos. 342, 343, 167-172, 224-232 (1958).

Pt. II. Sachs considers in detail results which show that the mechanism of V_2O_5 attack is twofold. Its fluxing action is discussed, and the several other mechanisms proposed for the second method of attack are compared. Secondary effects arising from the presence of a liquid phase in general, and from its specific physical and chemical properties are indicated.

Pt. III. Sachs discusses possible remedies. Means of removing or reducing the ash content, the use of additives to render the oxide harmless, and metallurgical remedies are indicated. 41 references.—MA 19513

4.3.2, 6.2.5, 6.3.21

Dissolution of Thorium in Mixtures of HNO_3 and HF. David G. Karraker. E. I. Du Pont de Nemours & Co. U. S. Atomic Energy Commission Pubn., DP-399, Sept., 1959, 16 pp. Available from Office of Technical Services, Washington, D. C.

Laboratory measurements of dissolution rates of thorium in mixtures of nitric and hydrofluoric acids show that thorium can be dissolved with practicable time cycles in large-scale processing. The corrosion of stainless steel during the dissolution of thorium is acceptable, except that when the thorium is coated with aluminum-silicon alloy, frequently used as a bonding material for aluminum cans, severe local corrosion of the stainless steel occurs at areas of contact with residual aluminum-silicon. This contact corrosion does not occur when the cans are hot-press-bonded to the thorium without aluminum-silicon. (auth) NSA. 19271

4.5 Soil

4.5.1, 6.3.8

The Systematology of the Corrosion of Metals in Soil. Pt. II. Lead. (In German.) T. Marković, M. Sevdić and N. Pavković. Werkstoffe u. Korrosion, **11**, No. 1, 22-27 (1960) Jan.

The second part of the investigation on the systematology of the corrosion of metals in soil is devoted to the behavior of lead and lead cables. Again, the corrosion phenomena taking place on the surface of the metal are of an electrochemical nature. The distribution of the anodic and cathodic zones on the lead surface depends on the size of the soil particles, on the water saturation condition of the soil, on the pH value of the soil, and on the duration of the test.

With the field tests, the dissolution rate of lead with 1 pC Sb and commercial lead has been clearly found dependent on the average annual rainfalls and on the pH value of the soil.

The corrosion-chemical behavior of the lead cable sheathing in soil is governed by stress corrosion. An initial localization of the corrosion phenomena is accomplished by plastic deformations which then cause electrochemical reactions. 19297

4.5.2, 6.2.3, 3.4.9, 3.6.8

Study of the Cathodic Polarization of Steel in Saline and Clayey Soils at Different Moisture Content. (In Russian.) I. A. Mamedov. Izvest. Akad. Nauk Azerbaidzhan, S.S.R., Ser. Fiz.-Tekh. i Khim. Nauk No. 6, 99-107 (1958).

Maximum corrosion of steel occurs at a soil moisture content of 25-30%. The potential of the steel under cathodic polarization at a pre-determined current density tended to shift sharply toward negative values with time and became stabilized after one month. 18890

4.5.1, 6.2.1, 6.3.6, 6.3.8

Long-Range Field Burial Study Probes Underground Corrosion. Iron Age, **182**, No. 15, 77-80 (1958) Oct. 9.

Chief causes of underground corrosion are described for widely varying soils. The discussion covers ferrous metals, copper, brass and lead. The method by which the groups were compared is explained. 3 figures.—ZDA. 19242

4.5.1, 6.3.6, 3.4.7

The Systematology of the Corrosion of Metals in Soil. Pt. III. Copper and Copper Alloys. (In German.) T. Marković, M. Sevdić and Lj. Rubinić. Werkstoffe u. Korrosion, **11**, No. 2 (Suppl.), 87-92 (1960) Feb.

Electrochemical laboratory investigations on a simple model system have shown that the performance of copper and copper alloys in soil is governed by two influences: the saturation condition, and the pH value of the soil. On the basis of a simple graphic presentation of the behavior of copper and copper alloys by means of a corrosion current and pH diagram, it has been possible to represent and evaluate the results of tests which had been carried out, in the course of the years, by the USA National Bureau of Standards concerning the corrosion-chemical behavior of metals in different kinds of soil in the United States. 19298

4.6 Water and Steam

4.6.1, 5.7.7, 5.8.2, 7.4.1, 8.1.1

Corrective Water Treatment Prevents Scale Deposit, Corrosion. J. L. Thornley. Bird-Archer Co. Heating, Piping & Air Conditioning, **31**, No. 8, 112-115 (1959) Aug.

While water is an excellent heat transfer medium for air conditioning, it has objectionable property of being able to dissolve solids and eventually deposit them as scale in water cooled systems. This formation can impede heat transfer, restrict water flow and cause and sustain corrosion. These problems are detailed as they affect 3 main types of water-using systems (humidity control, chilled water and condenser-compressor cooling water systems), and preventive measures are discussed. pH value of water should be maintained in neutral range of 6.5-7.5. However, control of pH alone is not a sufficient corrosion preventive and inhibitors must be used in most cases. These include chromates, phosphates, nitrites, zinc salts and various combinations of chromates and phosphates or chromates, phosphates and zinc salts. Growth of biological organisms and its control, and prevention of destruction of wooden parts are considered. Photos show build up of corrosion products in water line and rotting of wood caused by fungus organisms.—INCO. 18575

4.6.11, 3.3.1, 5.2.1, 5.4.8

Marine Corrosion. (In French.) G. Dechaux. Corrosion et Anticorrosion, **7**, 317-321 (1959) Sept.

Electrolytic corrosion of floating and stationary steel structures; effect of bacteria and other organisms and impurities found in sea water; cathodic protection and protection afforded by antirust paints.—RML. 19084

4.6.1, 6.3.17, 6.4.2, 6.3.20, 8.4.5

Problems of Fuel Element Corrosion in Water. J. E. Draley. pp. 314-328 from "Nuclear Fuel Elements." Book, 1959. Reinhold Publishing Corporation, New York 22, N. Y.

Corrosion behavior of alloyed and unalloyed uranium, aluminum alloys, zirconium alloys and stainless steel in water. 5 references.—RML. 19756

4.6.11, 6.2.3

Effect of Photosynthesis Upon the Corrosion of Steel in Sea Water. A. Hache, L. Barriety and J. Debyser. In

French: Corrosion et Anticorrosion, **7**, 56-61 (1959) Feb. In German: Werkstoffe u. Korrosion, **10**, 145-148 (1959) Mar.

Oxygen content in sea water is the decisive factor with regard to steel corrosion. Tests with sea water and with sodium chloride solution indicate that the corrosion of specimens tested is proportional to the concentration of oxygen in sea water or in the solution. 6 references.—RML. 18454

4.6.1, 6.3.17

Corrosion Studies in High Temperature Water on U-2W/O Zr Alloy Coextruded in Zircaloy-2. R. H. Tuxworth and F. H. Krenz. Atomic Energy of Canada, Ltd. Sept., 1958, 36 pp., AECL-702; CRMet-802. Available from Atomic Energy of Canada, Ltd., Chalk River, Ontario, Canada.

Samples of uranium-2 wt.% zirconium alloys sheathed in Zircaloy-2 were exposed to high temperature water. The Zircaloy sheaths were defected by drilling a small hole, allowing water to contact the uranium alloy. In the absence of a diffusion bond between the uranium alloy and the Zircaloy, very rapid corrosion occurred. The addition of 2 wt% zirconium to the uranium affects the corrosion rate very little, however, it may affect the release of activity to the water. Heat treating the uranium-zirconium alloy to produce a diffusion layer at the Zircaloy-uranium interface produces a corrosion-resistant layer between the sheath and core which can have a marked effect on the corrosion resistance of the element at a defect.—NSA. 18971

4.6.1, 3.2.2, 6.3.6, 7.4.2, 8.4.5

Four-Tower Water Treatment Test Facility. R. G. Murray and M. E. Tester. Goodyear Atomic Corp. U. S. Atomic Energy Commission Pubn., GAT-247, Sept. 23, 1958, 17 pp. Available from Office of Technical Services, Washington, D. C.

A four-tower water treatment test facility was built for the study of corrosion in copper condenser tubes. A two-by-two factional experiment was run using phosphate treated water at two levels of water velocity and two water temperatures. The system was operated continuously for ninety days after which the tubes were removed for inspection. After being split open, the tubes were visually inspected for pitting corrosion. Pits were found in the tubes from the two towers operating at low water velocity; these pits were more severe in the high temperature units. Slit deposits were much less in the low temperature, high velocity unit than in the other units. Subsequent tests will be made using a variety of corrosion inhibitors since results indicate that it is possible to simulate plant conditions in the laboratory. (auth.)—NSA. 18861

4.7 Molten Metals and Fused Compounds

4.7, 6.6.4

Action of Molten Uranium on Graphite. E. L. Swarts. Trans. Am. Inst. Mining & Met. Engrs., Met. Soc., **215**, No. 4, 553-554 (1959) Aug.

It has been shown that when molten uranium contacts graphite, a continuous carbide layer clads the graphite. This layer probably protects the graphite against more rapid corrosion, but is itself not stable toward molten uranium. —BTR. 18604

4.7, 2.4.2

Filtration of Molten Sulfur. J. R. Donovan and B. J. Barnett. Monsanto Chemical Co. Paper before American Chemical Soc., 133rd Mtg., San Francisco, April 1958. Ind. & Eng. Chem., **51**, No. 2, 165-168 (1959) Feb.

Work described was undertaken because of difficulties with porous carbon tube filters. Several test runs were made with this equipment to check performance, and subsequently study was made in vacuum, nutsche-type filter. Filter element consisted of 24 x 110 mesh, Dutch weave stainless steel wire cloth, sandwiched between 2 flat pipe gaskets. To precoat, 2.65 grams of filter aid were added to 1800 grams of molten sulfur filtrate at 144-155 C collected from previous run. Precoat mix was mixed thoroughly while Nichrome heating strips on equipment gave proper temperature. —INCO. 17741

4.7, 6.3.9, 6.3.13, 6.4.3, 8.4.5

Liquid Metal Fuel Reactor Experiment-Corrosion Resistance of Molybdenum-0.5% Titanium Alloy, Tantalum and Beryllium in Liquid Bismuth. J. W. Seifert. Babcock and Wilcox Co. U. S. Atomic Energy Commission Pubn., BAW-1067, May 14, 1959, 23 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C.

These tests were conducted to determine the corrosion resistance of molybdenum-0.5% titanium alloy, tantalum and beryllium to liquid bismuth at simulated LMFRE operating conditions. Sample coupons of molybdenum-0.5% titanium alloy, tantalum and beryllium were exposed to the LMFRE fuel solution (bismuth containing uranium, zirconium and magnesium additives) for 1000 hr in a tilting capsule test. The metals exhibited good corrosion resistance in the bismuth fuel solution. The weight changes observed for these specimens were small in some cases, about the same as the weight loss due to cleaning. The metallurgical examination indicated that no corrosive attack occurred. (auth.)—NSA. 18681

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.3, 8.9.1

Hull-Corrosion Prevention System. Corrosion Prevention and Control, **5**, No. 7, 53-55 (1958).

External corrosion of ship's hulls is prevented with impressed current supplied through long thin lead alloy anodes. The potential between the hull and the surrounding water is measured with a zinc electrode, the voltage from which is used to control automatically the current supplied to the anodes in order to maintain the hull within 10 mV. of its pre-set potential.—MA. 18134

5.2.1, 5.11, 8.9.3

Corrosion Control Incorporated Into Pipe Line Design and Construction. William R. Curley. West Virginia University, Technical Bulletin No. 52, 57-62 (1958) Oct.

Factors of electrical insulation and cathodic protection of a buried structure under protection from any other metal structure not under the same protective system.—BTR. 18752

5.2.1, 5.4.5, 8.9.5

Cathodic Protection of Shell Plating. J. P. O'Donovan. Corrosion Prevention and Control, **5**, No. 12, 49-50 (1958).

A brief discussion of some questions connected with cathodic protection of ships' hulls, including need for total protection, life of the anodes and the use of paint coatings.—MA. 18914

5.2.1

Internal Cathodic Protection. Pt. 4. The Long Thin Circular Tube with Internal Insulating Coating. C. Plumpton and C. Wilson. Corrosion Prevention and Control, **6**, 49-52 (1959) Oct.

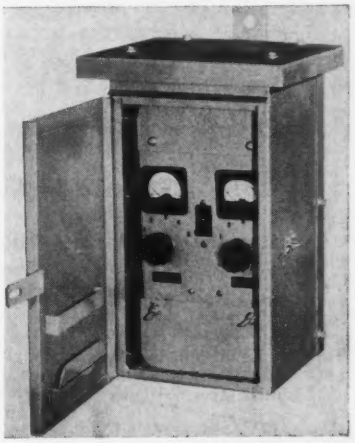
Derivation of expressions for anode separation, anode potential and current density for internally coated pipes having cathodic protection against water corrosion.—RML. 19404

Lester **COMPACT**

CATHODIC PROTECTION RECTIFIERS

For Tanks and Gas Distribution Networks

• Small size • Light weight • Electrical components de-rated for long, useful life. • High conversion efficiency • Voltage selection in small increments • Convection cooled • Economically priced



10 Vdc 8 Amps • 20 Vdc 9 Amps

LESTER EQUIPMENT MANUFACTURING CO., INC.

151 W. 17th St. Los Angeles 15, Cal.

MANUFACTURERS OF AC TO DC EQUIPMENT SINCE 1932

5.2.1, 1.2.2, 4.5.1, 4.6.1

Cathodic Protection of Steel Structures in Water and in Soil. Otto Bess. Elektrotechn. Z., **10B**, No. 6, 233-236 (1958).

Bess describes the corrosion process and methods of cathodic protection. Technology and economics are discussed with examples. 13 references.—MA. 19682

5.2.1, 8.3.4

How Cathodic Protection in Breweries Saves Money in Corrosion Prevention. John A. Michelson and Gerard L. Power. Modern Brewery Age, **58**, 42, 45-46 (1958) Dec.

5.2.2, 4.6.7

Zinc Anodes for Cathodic Protection. (In French.) R. Souské. Corrosion et Anticorrosion, **7**, No. 3, 79-82 (1959) March.

Principle of cathodic protection and the use of zinc anodes for protecting underground structures and metals in contact with fresh water are discussed. It is stated that the zinc used must be at least 99.996% pure and, generally, should contain a small amount of aluminum or magnesium to counteract the effect of impurities.—ZDA. 18606

5.3 Metallic Coatings

5.3.4, 8.8.3

Recent Developments in Chromium Plating. D. E. Weimer. Metal Finishing J., **5**, No. 51, 89-97 (1959).

Weimer describes recent work on factors influencing chromium deposition, the use of spray suppressants, and automatic plating machines and the development of processes for crack-free chromium deposition. 14 references.—MA. 19544

5.3.4

Nickel Plating of Wire and Wire Products. The Kanigen Process. Donald E. Stewart. Wire and Wire Prods., **34**, No. 8, 978, 1013-1015 (1959).

The Kanigen coating has a resistivity ~9 times that of Ni, and 3 times that of Cu. It is non-porous, with a hardness of 49 Rockwell C; this can be increased to 69 by heating to 750 F (400 C). After heating to 1200 F (650 C) the abrasion-resistance is > that of hard-Cr. Wrought and cast Fe, steel, Cu, brass, bronze, Al, Mg, Ti and Be can be treated, but Zn, Pb, Cd, Sn, Bi and Sb cannot. Since plastics, glass and ceramics can be plated, the process is well-suited to printed circuits. Plating methods are outlined.—MA. 19525

5.3.2

Corrosion Data for Chemical Nickel Plating. J. Robert Spraul. Plating, **46**, 1364-1369 (1959) December.

Electroless Ni plating can make a definite contribution to decreasing corrosion losses of structural materials from either chemical or weathering attack. Data for corrosion tests on Ni-plated 1010 steel. 20 references.—RML. 19522

5.3.4, 8.4.3

Offshore Corrosion Costs Cut by Cold Galvanizing. World Oil, **148**, 234, 238, 242 (1959) Jan.

Applying an inorganic silicate filled with metallic zinc to sand blasted metal surfaces, followed by a "curing" solution, gives excellent long-wearing protection in highly corrosion areas; better than conventional galvanizing.—MR. 19588

5.3.2, 8.8.3

Automatic Bright Zinc and Cadmium Plating for Corrosion Protection. K. N. Sinclair. Corrosion Prevention and Control, **6**, No. 1, 43-44 (1959) Jan.

First describes the advantages and merits of cadmium and zinc plated coatings with regard to their appearance, corrosion resistance and ductility. The advantages of an automatic plating plant are said to be lower prices, improved appearance, and speeding of deliveries of work, but such plant is only suitable for large throughputs. 3 figures.—ZDA. 18598

5.4 Metallic Coatings and Paints

5.4.5

Modern Organic Coatings. Eugene W. Kanning. Plating, **46**, No. 3, 253-256 (1959).

Titanium dioxide has six times the covering power of white lead and is far more durable. Natural oils are being superseded by by-products of petroleum, and alkyd resins find increasing use. A number of other resins are discussed. —MA. 19258

5.4.8, 3.4.9

High-Humidity Applications. D. E. Wilbur. Building Res. Inst. (Washington). Conf. on Field Appl. Paints and Coatings, 1958, **1959**, 71-74.

This paper examines the problems faced by the maintenance man who must apply paint to equipment and machines during operating hours in such places as textile mills, laundries, food processing plants or bottling plants where humidity is necessarily high. The need for selecting paints which can be applied on damp surfaces or in damp atmospheres is stressed. Various types of paint which will give good performance on exterior masonry walls are detailed, as well as those which will not perform well. The painting of interior walls and ceilings under high-humidity conditions, posing an entirely different set of problems, is discussed and the testing of special paints for this purpose is described. Painting of various types of metal structures exposed to high humidity and the formulation of paints designed to prevent rust and deterioration are also included.—RPI. 19595

5.4.5

The Painting of Machinery Components. B. van der Bruggen. Metal Finishing J., **5**, No. 49, 12-18, 21 (1959).

The importance of adequate drying time and the advantages of accelerated drying are stressed. A typical modern Swiss conveyorized spray-painting installation is described.—MA. 19548

5.4.5, 8.9.5, 4.6.11, 4.6.7

Paints for the Protection of Ships and Structures Against Corrosion in Water. (In Czech.) A. Trdlica, M. Svoboda and C. Lvovsky. Korose a Ochrana Materiálu, **3**, No. 3-4, 41-45 (1959).

During a discussion on the use of paints for protection against corrosion in water, it is stated that the development of the Czech shipping industry has created a demand for paints protecting against corrosion in sea water as well as fresh water. Such paints are based on coumarone resins and drying oils or polystyrenes, with zinc chromate and zinc dust. These types resist corrosion in synthetic sea water for over a year. It is proposed to use hard zinc as the source of the zinc dust. 3 figures, 1 table.—ZDA. 19559

5.4.5

The Development of Neoprene Coatings for the Protection of Chemical Apparatus. (In German.) M. Tixier. Werkstoffe u. Korrosion, **10**, No. 2, 70-73 (1959).

The history of vulcanized-rubber protection for chemical plant is given, as well as the properties desired from such coatings. The Neoprene N.9. coating is described; it has Shore hardness 60, elongation to fracture 500-550 percent, breaking strength 150-160 kg/cm², and elastic modulus at 200 percent elongation 45-50 kg/cm². Method of application is given together with examples of its use in special equipment.—MA. 19571

5.4.3

Manufacture and Applications of PTFE Lined Pipes and Components. T. R. Thierry. Pipes and Pipelines, **4**, 30-32, 36 (1959) Dec.

Chemical inertness and thermal stability give Teflon polytetrafluoroethylene materials optimum properties as almost corrosion-proof linings for steel pipe at temperatures from —72 to 260 C. Problems and methods of fabrication; industrial applications.—RML. 19572

5.4.5, 1.6

Hot Organic Coatings. R. B. Seymour. Book, 1959, 233 pp. Reinhold Publishing Corp., New York; Chapman & Hall, London.

Hot-melt coatings have been known for a long time, but it is only in recent years that real progress has been made in their use. The appearance, therefore, of this general conspectus on hot organic coatings is well timed. The author has treated his subject briefly but adequately, giving data on physical properties, chemical resistance, formulations and industrial application of a wide range of organic materials by hot application techniques. The emphasis is American but engineers and technologists in the United Kingdom, also, should obtain much useful and easily found information on coatings for a wide variety of substrates used in many industries.—RPI. 19449

5.4.5

Lanolin Paints. J. Seston. Corrosion Prevention and Control, **6**, No. 9, 48-50 (1959) Sept.

The properties and uses of anti-corrosive paints based on lanolin are described. A pigmented lanolin preparation can either be left indefinitely and treated as a permanent coating or it may be used as a primer, or, again, it can easily be removed.—RPI. 19464

5.4.5, 6.2.1, 5.9.4

Paints for Iron and Steel Work. (In Russian.) B. V. Lyubimov. Vestnik Mashinostroeniya (Bulletin of Machine Building), **38**, No. 3, 59-63 (1958).

Various factors involved in the effective protection of iron and steel, especially against corrosion, are discussed. Materials for paint formulation are tabulated in considerable detail, according to conditions of exposure: maritime, tropical, chemical, etc., both for primer and upper coats, air-dried or stoved. Different kinds of conditions of phosphatizing are included. In all cases three classes of quality finish are specified according to severe, medium or light conditions of use. Special attention is given to filling and other surface treatment both before and after the primer. The various drying methods are discussed.—RPI. 18881

5.8 Inhibitors and Passivators

5.8.1, 4.4.7, 7.1

The Inhibiting Effect of Zinc Dithiophosphates in Modern Engine Oils on Corrosion and Wear. R. Larson. Schweiz. Arch. angew. Wiss Techn., **25,** No. 2, 54-61 (1959).

Zinc dithiophosphates fulfill all the requirements of an engine-oil additive, being effective high-pressure additives under boundary lubrication conditions. The properties of different types are compared.—MA. 19274

5.8.2, 4.4.3

Corrosion Inhibitors for Cast Iron and Other Metals in Ethylene Glycol Solutions and in Mains Water. A. D. Mercer and F. Wormwell. J. Applied Chem., **9,** 577-588 (1959) Nov.

Effect of sodium benzoate and nitrate in preventing corrosion in ethylene glycol solutions of cast iron, copper, aluminum, mild steel and composite samples. —RML. 19301

5.8.2, 4.4.3

Corrosion Inhibitors for Ethylene Glycol Solutions, with Particular Reference to Cadmium-Plated and Terne-Plated Steel. A. D. Mercer and D. M. Brasher. J. Applied Chem., **9,** 589-594 (1959) Nov.

Tri-ethanolamine phosphate and sodium mercaptobenzthiazote as corrosion inhibitors in ethylene glycol solutions. Weight loss is determined and correlated with visual observations.—RML. 19302

5.8.4

Corrosion Inhibitors. Alan MacKenzie and Marshall Dick. Soap and Chemical Specialties, **35,** 79-81 (1959) Nov.

Results of tests on aluminum, copper, lead, magnesium, brass, galvanized steel, ASTM A7-49T steel, 304 stainless steel and tinplate using Na_3PO_4, Na_2HPO_4 and NaH_2PO_4 as inhibitors.—RML. 19306

5.8.1, 4.4.7

Rust Inhibitors. Sci. Lubrication, **11,** No. 9, 19-20 (1959) Sept.

Geigy Co.'s Sarkosyls and Amine O rust inhibitors (N-methylglycine derivatives and a substituted imidazoline, respectively) can be used separately or together. When combined with a fatty acid or Sarkosyl acid, Amine O is an excellent corrosion inhibitor and has excellent water-displacing properties, and controls the color, sludge and water emulsification of fuel oils at concentrations of < 0.01 percent. In grease manufacture, 2-10 percent bentonite and 0.5-2 percent Amine O may be blended into mineral oil at 100 C in a colloid mill. Addition of 0.5 percent of a 1:1 Sarkosyl O: Amine O mixture to a commercial transparent oil and a conventional soluble cutting oil eliminated corrosion of steel in tests at 50 percent humidity. 19477

5.9 Surface Treatment

5.9.1, 5.4.5

Industrial Metal Finishing with Paints and Organic Coatings. A Survey of Modern Practice and Techniques. J. J. Stordy and W. G. J. Appleton. Metal Finishing J., **5,** No. 54, 223-236 (1959). Metal Finishing Absts., **1,** No. 4, 148 (1959).

A comprehensive review of pretreatment, including cleaning and phosphating, paint finishes, painting plant, application methods, including spraying, dipping, electrostatic, hot and airless spraying, flow coating and stoving ovens.—RPI. 19532

5.9.4

Black-Oxide Finish Fights Corrosion, Reduces Friction on Most Metals. Bruce U. Smith. Western Metalworking, **17,** No. 2, 46-47 (1959).

Processes for imparting black-oxide protective coatings, 0.00025-0.00045 in. thick on iron, steel, copper, brass, bronze and zinc alloys, are reviewed. A typical black-oxiding solution contains 65:35 KOH-KNO_3 heated to 305 F (150 C).—MA. 19488

5.9.4

The Impedance, Rectification, and Electroluminescence of Anodic Oxide Films on Aluminium. Archibald W. Smith. Can. J. Physics, **37,** No. 5, 591-606 (1959) May.

An experimental investigation was made of the impedance, rectification and electroluminescence of anodic oxide films formed on aluminum, in an electrolyte of boric acid and ammonium hydroxide. These properties were studied, where appropriate, as a function of the surface condition before anodization, the formation voltage, the conductivity of the electrolyte and the frequency. A constant-voltage formation technique was used. The interpretation of the results suggests that the oxide itself is a good dielectric, but that the film contains defects whose number and form depend on the conditions of formation. The defects appear to control the rectification and electroluminescence, and have an appreciable influence on the impedance. The frequency dependence of the capacitance was much smaller than that found by previous workers although there was an appreciable contribution arising from the geometrical effects in the electrolytic cell. The zero-thickness potential for the film was found to be in agreement with a theoretical estimate. (auth)—ALL. 19489

6. MATERIALS OF CONSTRUCTION

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.6,3.5.8,3.7.4,3.7.2

Stress-Corrosion Cracking Properties of Corrosion Resisting Copper Alloy "Albrac." (In Japanese.) Rihei Kawachi and Mutsumi Okawa. Sumitomo Metals, **10,** 105-110 (1958) April.

Albrac alloy tubes with different grain sizes were subjected to sinking and mercurous nitrate testing to determine the effects of grain size, plastic deformation and silicon, titanium or phosphorus additions on stress-corrosion properties. Relation between percentage reduction by sinking, internal stress and resistance to cracking. Titanium, silicon or phosphorus addition improved resistance to stress-corrosion. Variation of internal stress with specimen length. 9 references.—RML. 18814

6.3.17, 3.8.2

Electrochemical Behaviour of Uranium: Equilibrium Voltage/pH Diagram of the System U-H_2O at 25 C. (In French.) E. Deltombe, N. de Zoubov and M. Pourbaix. Proc. Internat. Cttee. Electrochem. Thermodynamics and Kinetics, Madrid, 1956, **1958,** 258-269. Available from Butterworths Scientific Publications, 88 Kingsway, London WC2, England.

General properties of uranium and its oxides are considered on the basis of the diagram. Stability and electrolytic preparation of metallic uranium are among the aspects discussed. 33 references.—MA. 18825

6.3.16, 3.8.2

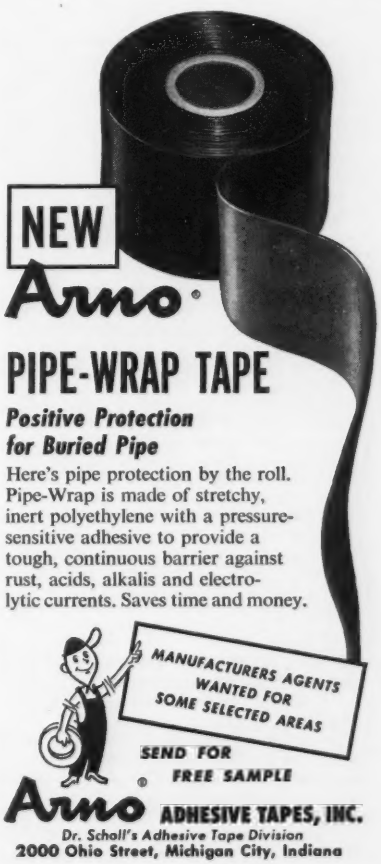
Electrochemical Behaviour of Tungsten: Equilibrium Voltage/pH Diagram of the System W-H_2O at 25 C. (In French.) E. Deltombe, N. de Zoubov and M. Pourbaix. Proc. Internat. Cttee. Electrochem. Thermodynamics and Kinetics, Madrid, 1956, **1958,** 250-257. Available from Butterworths Scientific Publications, 88 Kingsway, London WC2, England.

General properties of tungsten and its oxides are considered on the basis of the diagram. Special reference is made to the stability, corrosion and electrodeposition of the metal. 32 references.—MA. 18824

6.3.9, 3.8.2

Electrochemical Behavior of Molybdenum: Equilibrium Voltage/pH Diagram of the System Mo-H_2O at 25 C. (In French.) E. Deltombe, N. de Zoubov and M. Pourbaix. Proc. Internat. Cttee. Electrochem. Thermodynamics and Kinetics, Madrid 1956, **1958,** 238-249. Available from Butterworths Scientific Publications, 88 Kingsway, London, WC2, England.

General properties of molybdenum and its oxides are considered on the basis of the diagram. Special reference is made to the stability, corrosion and electrodeposition of the metal. 44 references.—MA. 18823


NEW
Arno
PIPE-WRAP TAPE
Positive Protection for Buried Pipe
Here's pipe protection by the roll. Pipe-Wrap is made of stretchy, inert polyethylene with a pressure-sensitive adhesive to provide a tough, continuous barrier against rust, acids, alkalis and electrolytic currents. Saves time and money.
MANUFACTURERS AGENTS WANTED FOR SOME SELECTED AREAS
SEND FOR FREE SAMPLE
Arno ADHESIVE TAPES, INC.
Dr. Scholl's Adhesive Tape Division
2000 Ohio Street, Michigan City, Indiana

6.3.20, 3.8.4, 3.7.2

High-Temperature Oxidation of Zirconium and Its Alloys in Dry Oxygen. (In Japanese.) Yotaro Murakami, Hirozo Kimura and Keikichi Inoue. Suiyokwai-Shi (Transactions of the Mining and Metallurgical Alumni Assoc.), **13,** No. 7, 587-590 (1958).

Oxidation of zirconium was found to obey a parabolic-rate law. The activation energy was calculated at 30.4 kcal/mole. Oxidation was reduced by addition of tin and considerably by germanium. Niobium improved elevated-temperature strength without reducing oxidation-resistance.—MA. 18864

6.3.6, 3.8.2

Electrochemistry and Corrosion: Recent Work in Russia. Corrosion Prevention and Control, **5,** No. 2, 42-43 (1958).

Corrosion rates and limiting cathodic current density were measured for copper corroding in dilute nitric acid at 25, 60 and 90 C. Except in concentrations above 7.8 mole/l corrosion-rate was equivalent to the cathodic current density. At 25 C at concentrations of 10.2 and 12.5 mole/l corrosion-rate was < the current density; the formation of surface cupric oxide is suggested as a reason for this. The mechanism of dissolution and determination of corrosion-rates from the cathodic current density is discussed.—MA. 18856

6.3.8, 4.3.2, 4.3.5, 8.10.2, 8.8.1

Use of Lead in Chemical and Metallurgical Plant Construction. A. Turner, J. R. Wellington and L. Williams. Paper before Joint AIChE-CIC Chem. Eng. Conf., Montreal, April 20-23, 1958. Can. J. Chem. Eng., **37,** No. 2, 55-64 (1959) April.

Use of lead in chemical and metallurgical operations of Consolidated Mining & Smelting Co. of Canada Ltd. at Trail, B.C. A wide variety of corrosive environments are encountered, including phosphoric and sulfuric acids, sulfur dioxide, fluorides and ammonium sulfate. Except in presence of fluorine compounds, 6% antimonial lead is more resistant to corrosion than is soft lead. Data tabulated include results of comparative tests on lead, 6% antimonial lead and Type 316 exposed in various sections of plant ventilating and fume recovery systems, and corrosion rates of various metals exposed to a gypsum/phosphoric-sulfuric acid slurry, exposed in fluorine removal equipment (phosphate fertilizer plant), in jet condenser of ammonium sulfate plant, in sulfur dioxide (zinc roaster) gas cooling (Glover) tower, exposed to ventilating gases from lead smelter sinter crushing plant, and exposed to 93% sulfuric acid; materials include Types 304, 310, 316, 347, 410 and 446, Nionel, Hastelloy B, and C, Monel, Chromel-A and Carpenter 20. Mechanical properties of lead are reviewed with particular reference to its high specific gravity, low mechanical strength, creep and fatigue properties. Graph, tables, diagrams, 17 references. —INCO. 18631

6.3.10, 4.4.7

Studies on the Dry Corrosion of Niomonic 80A by Peat Ash. J. A. Waddams and J. C. Wright. Metallurgia, **59,** 161-164 (1959) April.

An account is given of the effects of typical peat ashes on Niomonic 80A at temperatures of 700-800 C. Previous work on related aspects of the dry corrosion of high nickel alloys is reviewed. The present study confirms the opinion that the form of accelerated oxidative corrosion considered is preceded by sulfidation, particularly when alkali sulfate/chloride mixtures are involved. A critical examination of the process, using metallographic and X-ray diffraction techniques, is reported which indicates that when Niomonic 80A is subjected to these mixtures at elevated temperatures, the sulfidation process leads to the formation of chromous sulfide and Ni_3S_2 ahead of the oxidation front.—BTR. 18638

6.3.3, 4.2.1

Atmospheric Contamination of Chromium and Its Effect on Mechanical Properties. G. R. Wilms and T. W. Rea. Australian Defense Scientific Service, Melbourne. J. Les-Common Metals, **1,** 152-156 (1959) April.

Chromium heated in air at 950 C for 200 hrs. is contaminated to a considerable extent by nitrogen. This has a marked effect on the mechanical properties, especially the ductile → brittle transition temperature, the magnitude of the effect depending on the rate of cooling from 950 C. (auth)—NSA. 18636

6.3.16, 6.3.9, 3.5.9, 3.8.4

Oxidation of Tungsten and Molybdenum from 1800 to 2500. F. J. W. Semmel. pp. 510-519, from "High Temperature Materials," Book, 1959, John Wiley & Sons, Inc., New York 16, N. Y.

Specimens were tested in dry air flowing at 75 cu. ft. per hr. Molybdenum oxidizes linearly low between 1800 and 2500 F. Oxidation of tungsten undergoes transition from predominantly linear to parabolic oxidation as temperature is increased. 4 references.—RML. 18648

6.3.10, 3.7.4, 3.8.4, 2.3.9

Influence of Lattice-Defect Density on the Chemisorption and Oxide Formation on a Clean (100) Crystal Face of Nickel as Determined by Low-Energy Electron-Diffraction. (In English.) H. E. Farnsworth and Johannes Tuul. Physics Chem. Solids, **9,** No. 1, 48-56 (1959).

With increasing exposure to oxygen, adsorption on an at. clean carbon-free (100) single-crystal nickel face occurred successively in double-spaced f.c. crystals, single-spaced simple-sq., and nickel monoxide-type lattices. Diffraction-pattern intensities were greater with high defect d, and longer oxygen exposures were required to form a detectable amount of oxide at 150 than at 25 C. Certain exposure and heat-treatment conditions gave additional lattice structures.—MA. 19141

6.3.6, 3.7.4

Contribution to the Study of Cuprous Oxide Seed Formation on Single-Crystal Copper. (In French.) (Mme) Josiane Bougnot and Nicolas Nifontoff. Compt. rend, **248,** No. 11, 1683-1686 (1959).

Observations on the formation, by controlled oxidation, of cuprous oxide seeds on the (100), (110), (111) and (311) faces of the copper are reported. —MA. 19044

6.3.15, 3.8.4

Sorption by Titanium of Oxygen and Nitrogen at Low Pressures. L. G. Carpenter and W. N. Mair. J. Inst. Metals, **88,** No. 1, 38-43 (1959-1960).

Rate of sorption, at pressures of the order of 0.1 μ mercury, of oxygen by titanium was measured by a continuous-flow technique already described (J. Sci. Instruments, **34,** 110, 1957; Card No. 14054 classified 2.4.2). Under these conditions there was no oxide scale and the probability, per impact, that an impinging oxygen molecule would react with β-titanium increased from 0.15 to 0.7 over the temperature range 1175-1525 K. For α-titanium in the range 1050-1153 K, the reaction probability was still of the order of 0.1. Changes of sorption rate and optical emissivity were used to detect the successive phase changes occurring on the surface of the titanium during oxidation. The phase changes were identified by comparison of the amount of oxygen absorbed with the published equilibrium diagram, and by metallographic and X-ray examination of specimens quenched in mercury. A closed-volumetric technique was used to measure the kinetics of the titanium/nitrogen reaction at pressures of the order of 1 μ mercury. The reaction probability was found to increase with temperatures from 6×10^{-5} to 8×10^{-4} over the range 1040-1220 K, with a discontinuity at the $\alpha \rightarrow \beta$ transition temperature (1153 K). (auth)—MA. 19067

6.3.15, 3.7.2, 3.6.5, 3.8.3

Influence of Noble Metal Alloy Additions on the Electrochemical and Corrosion Behavior of Titanium. Milton Stern and Herman Wissenberg. Union Carbide Metals Co. J. Electrochem. Soc., **106,** No. 9, 759-764 (1959) Sept.

Alloying of titanium with small amounts of noble metals markedly improves its corrosion resistance in reducing-type acids without any impairment of its high resistance to oxidizing media. The mixed potentials of titanium noble metal alloys are more noble than the critical potential for passivity of titanium in the same environment. Passivity is observed in hydrogen-saturated systems without the presence of a redox system more oxidizing than the hydrogen electrode. The mixed potential of titanium noble metal alloys is much more sensitive to traces of oxidizing agents than unalloyed metal. 18560

6.3.10, 4.3.3, 4.3.5

Attack of Nitrogen on Various Heat Resistant Alloys. (In Dutch.) C. Vollers. Metalen, **14,** 41-42 (1959) Feb. 14.

Exposure of nickel-chromium-iron alloys, a nickel-iron alloy and pure nickel at 500 C in an atmosphere of anhydrous ammonia for a period of 1540 hrs. With high nickel content, a protective film of nitrides forms. Corrosion resistance against nitrogen is also increased by chromium.—RML. 18592

6.3.10, 3.8.4, 3.5.9

Initial Oxidation Rate of Nickel and Effect of the Curie Temperature. (In English.) H. Uhlig, J. Pickett and J. Macnairn. Acta Metallurgica, **7,** 111-117 (1959) Feb.

Nickel foil was oxidized for 24-hr. periods within the temperature range 307-422 C producing nickel monoxide films up to 3400 A thick maximum. A discontinuity in oxide growth is observed at the Curie temperature (353 C). Data obtained at 390, 394 and 405 C as a function of time show that a two-stage oxide growth rate occurs, a higher rate following an initially lower rate. Both stages are represented by a linear relation between oxide thickness and logarithm of time. Many initial oxidation rate data obtained by other investigators, for nickel and a variety of metals, also follow the two-stage logarithmic equation. Based on control of the initial oxidation rate by electron transfer from metal to oxide, the discontinuity of oxide thickness at the Curie temperature is explained by an observed work function of

nickel slightly higher above the Curie temperature than below. 26 references. —BTR. 18593

6.3.15, 3.4.8, 3.8.2

Studies on the Mechanism of Electrochemical Corrosion of Titanium. Pt. I. Effect of Halide Ions on the Corrosion and Electrochemical Behavior of Titanium in Sulfuric Acid. (In Russian.) N. D. Tomashov and R. M. Al'tovskii. J. Phys. Chem., USSR (Zhur. Fiz. Khim.), **33,** 610-616 (1959) Mar.

Corrosion behavior of titanium is determined by the presence of a protective oxide film on its surface. The halide ions Cl^- and Br^- in sulfuric acid in an atmosphere of air and of hydrogen have a double effect on the corrosion of titanium activating it in dilute acid solutions and retarding the corrosion in more concentrated solutions. In all sulfuric acid solutions studied I^- ions passivate titanium in air, whereas in hydrogen this is true only for concentrated solutions. The retardation of titanium corrosion by halide ions may be explained by their forming adsorbed or phase protective films on the titanium surface. The dissolution of titanium in sulfuric acid obeys the laws of electrochemical kinetics. (auth)—NSA. 18579

6.3.11, 2.3.5, 3.8.4

Oxidation of the Silver Electrode in Alkaline Solutions. Thedford P. Dirkse. J. Electrochem. Soc., **106,** No. 11, 920-925 (1959).

Formation of Ag_2O and AgO was examined by constant current and constant-potential methods. The efficiency of the processes was measured by weight gains. Polarization was obtained from an interrupted-current technique. Oxide formation and oxygen evolution are discussed. 16 references.—MA. 19730

6.3.6, 3.4.8

Dissolution of Metals and Alloys. Pt. I. Dissolution of Copper in Solutions Containing Persulphate Ion. G. C. Bond, B. M. Hill and R. Tennison. J. Chem. Soc., **1959,** 33-38, Jan.

Copper readily dissolves at room temperatures, but the reaction is transport controlled at all concentrations up to 0.1 M above 35°. 11 references.—RML. 19718

6.3.6, 7.2, 3.6.6, 3.5.3, 3.6.9

Deterioration and Protection of Copper Piping. (In French and German.) Kurt P. Camenisch. Pro-Metal, **12,** 217-224 (1959) Oct.

Possibilities of chemical, electrochemical and galvanic corrosion; erosion; effect of stray currents and fatigue cracks; protective measures. Corrosion of copper piping rarely occurs.—RML. 19656

6.3.13, 6.3.5, 3.2.2, 4.3.3, 4.6.2

Corrosion by Chemicals, Gases and Liquid Metals. pp. 431-543 from "Metallurgy of the Rarer Metals. No. 6. Tantalum & Niobium." Book, 1959, Academic Press, Inc., New York 3, N. Y.

Chemical corrosion of Ta and Nb and their alloys. Embrittlement of Ta and Nb by alkalis and in uranyl sulfate solution; reaction to water and steam; electrochemical behavior and properties of oxide films. 120 references.—RML. 19616

6.3.12, 6.3.16, 3.2.2

Behavior of Rhenium in Electron-Tube Environments. Gordon B. Gaines, Chester T. Sims and Robert I. Jaffee. J. Electrochem. Soc., **106,** No. 10, 881-885 (1959).

Rhenium, tungsten and rhenium-coated tungsten were exposed to carburizing atmospheres and to water-cycle attack, rhenium and tungsten to aluminum oxide at 1750 C for 7000 hr., and rhenium to boron-containing compounds. Rhenium does not form a carbide, even though carbon diffuses quite rapidly through rhenium. Rhenium forms a boride and maintains structural and mechanical integrity after contact with aluminum oxide. Rhenium shows excellent resistance in the water-cycle test.—MA. 19144

6.3.5, 3.2.3, 3.7.2, 2.3.9, 3.8.4

Some X-Ray Observations on the Oxidation Characteristics of Binary Niobium Alloys. Ralph H. Hiltz. pp. 71-77 of "Proceedings of the Seventh Annual Conference on Industrial Applications of X-ray Analysis, August 13-15, 1958, Denver, Colorado." Book, 1959, 359 pp. William M. Mueller, editor. University of Denver, Denver, Colorado.

Knowledge of the effect of alloying on the oxidation characteristics of niobium is limited almost entirely to oxidation rate and oxygen diffusion rate data. In an effort to determine the mechanism by which alloying elements increase or decrease the oxidation rate of niobium, an x-ray study of niobium alloys was performed. Both X-ray diffraction and fluorescent studies were conducted on the base metal before and after oxidation, on the scale formed, and on the interface between the metal and the scale. From the data obtained, a definite description of the mechanism was not possible, but it appears that the niobium monoxide film between the metal and the niobium pentoxide scale is the rate controlling factor. The elements titanium, molybdenum, chromium, tungsten and vanadium which produce a substantial improvement in oxidation resistance effect the formation of a second oxide structure within the niobium monoxide film. All the elements which provide a measurable increase in oxidation have either a similar ionic size or a 3+ valence state and in most cases have both. Elements not having a 3+ valence state or similar ionic size, i.e., copper, manganese, silicon and zirconium, do not improve oxidation resistance, in fact silicon and zirconium act to eliminate the niobium monoxide film and the oxidation rate of these alloys is greater than pure niobium. (auth) —NSA. 19194

6.3.15, 8.8.5

Development and Evaluation of a High-Temperature Titanium Alloy. G. T. Harris, H. C. Child and A. L. Dalton. J. Inst. Metals, **88,** No. 3, 112-120 (1959-1960).

Development of a high-temperature titanium alloy, Hylite 50, is described. Useful creep strength could be retained up to 450 C in an α/β alloy containing aluminum 4, molybdenum 4, tin 2 and silicon ½%. The function of these various alloying elements is described. The optimum combination of tensile and creep properties was achieved by air-cooling the alloy from 900 C and ageing for 24 hrs. at 500 C. A study of forging and rolling temperatures and reductions indicated that when the alloy was given this heat-treatment, its properties were substantially independent of fabrication history. In contrast, if the alloy was subjected to stress-relief at 650 C, the creep and mechanical properties varied widely with different fabrication methods. The physical and mechanical properties of bar material which had undergone this optimum heat-treatment were evaluated, including creep and rupture strength, fatigue strength over a range of temperature in the plain and notched conditions, embrittlement characteristics, and sensitivity to hydrogen contamination. The creep and fatigue properties are compared with those of other titanium alloys. (auth)—MA. 19207

6.3.10, 3.7.4, 3.8.4, 2.3.9

Tests With Low-Energy Electron-Diffraction for Adsorbed Hydrogen and Nickel-Hydroxide Formed on the (100) Surface of a Nickel Crystal at 25 C. (In English.) H. E. Farnsworth, R. E. Schlier and Johannes Tuul. Physics Chem. Solids, **9,** No. 1, 57-59 (1959).

A pattern was obtained from a chemisorbed double-spaced monolayer after exposure to hydrogen only when a hot filament had been present during the exposure, indicating adsorption of atomic hydrogen and/or water vapor. The double-spaced structure was evidently due to water vapor. Hydrogen adsorption on some parts of clean nickel surfaces in the absence of a hot filament was confirmed by consecutive exposures to hydrogen and water vapor to form Ni $(OH)_2$.—MA. 19142

6.4 Non-Ferrous Metals and Alloys—Light

6.4.4, 5.4.5

New Coating Gives Magnesium Extra Protection. Iron Age, **181,** No. 2, 64-66 (1958) Jan. 9.

Magnesium's high strength-to-weight ratio is solving countless weight problems in virtually every field, and especially on aircraft and missiles, In some applications it is necessary to protect magnesium against abrasion, corrosives

You'll need me in your chimneys

Large industrial chimneys present a real problem in protection. They must withstand high temperatures, corrosive gases and moisture condensation. For more than 25 years, Sauereisen Acid-Proof Cement No. 31 has proved itself superior in over 200 chimney installations throughout the world. Ask for Data Sheets.

Sauereisen Cements Co.
Pittsburgh 15, Pa.

SAUEREISEN
Acid-Proof CEMENT **No. 31**

9a

such as salt air and certain acids and galvanic corrosion when it is coupled with dissimilar metals. One of the more successful approaches to coating magnesium has been chemical conversion treatments such as Dow 17, Dow 7 and coupling Dow treatment with Pt. 401, a new coating developed by Product Techniques, Inc. New Material is an air-drying thermosetting copolymer resin to which a catalyst is added just prior to use. It adapts to a variety of drying times, from 4 hours at room temperature to a half-hour at 140 F. Resin has been applied to chemical tanks, ventilating stacks subject to acid fumes and interior of pipes carrying salt and acid solutions. Its adherence to steel, aluminum alloys and plastics is good if they are properly pretreated. Photos.—INCO. 19247

6.4.2, 4.3.6, 4.3.7

Wet and Dry Corrosion Tests on AC4C and AC7B Aluminum Casting Alloys. (In Japanese.) Takuichi Morinaga, Shigeo Zaima and Chan Hing Hong. Light Metals, **9,** 45-51 (1959) Sept.

Characteristics of the alloys in 3% sodium chloride, 0.15% hydrogen peroxide solution.—RML. 19324

6.4.2, 4.3.7, 4.3.3, 3.2.2

Influence of H_2O_2 on Aluminum Corrosion in Alkaline Solutions, with Reference to the Formation of "Aluminum Blacks." (In Italian.) G. Caprioglio, P. Cipolli and F. Mazza. Chimica e l' Industria, **42,** 30-40 (1960) Jan.

Tests were carried out at different temperatures with varying NaOH and H_2O_2 concentrations. H_2O_2 in high concentrations displays an inhibiting action, while in lower concentrations the corrosion shows a characteristic behavior; a black film is formed. The protecting effect of this film is poor and of limited life because it cracks, and crosspoints of cracks become points of preferred attack with start of pitting corrosion.—BTR. 19664

6.4.2, 4.6.1

Corrosion Resistance and Mechanical Properties of Aluminum Powder Products. J. E. Draley and W. E. Ruther. Argonne National Lab. U. S. Atomic Energy Commission Pubn., ANL-5927, March, 1959, 10 pp. Available from Office of Technical Services, Washington, D. C.

Experimental extrusions were prepared from mixtures of atomized aluminum alloy and several powdered additives, including SiO_2, $AlPO_4$ and Al_2O_3. Some of the extrusions failed during corrosion testing in water at 290 and 350 C. Others corroded in approximately the same fashion as wrought X8001 alloy. The ultimate tensile strengths of these extrusions at 316 C were approximately two and one-half times greater than that of wrought X8001 alloy. (auth.)—NSA. 19763

6.4.2, 3.5.9, 3.7.2

Oxidation Losses of Molten Aluminium and Its Alloys. (In Polish.) S. Balicki and J. Leitl. Prace Inst. Hutn., **11,** No. 2, 71-74 (1959).

At 700-900 C the oxidation rate of aluminum-zinc, aluminum-copper, aluminum-silicon alloys increases linearly with temperature. With aluminum-silicon alloy it also increases with increase of silicon content. The oxidation rate of aluminum-magnesium alloy is several times higher than that of other alloys and is not linear, probably because of rapid oxidation of magnesium.—MA. 19018

6.4.2, 8.1.2, 4.2.1

Use of Light Metal in the Buildings of a Swiss Concern in The Paper and Fibre-Board Industry. (In French and German.) R. Blum. Aluminium Suisse, **9,** No. 21, 47-58 (1959).

Describes the use of aluminum in various forms, mainly for outside walls and roofing, in single-story buildings where the slightly acidic, moisture-laden atmosphere causes rapid deterioration of conventional structures.—MA. 19038

6.4.2, 4.6.1, 3.7.1, 3.2.3, 8.4.5

Corrosion of Aluminum Alloys in High Temperature Water. A Survey. Ketil Videm. J. Nuclear Materials, **1,** 145-153 (1959) July.

Autoclave and loop tests to determine effect of temperature, heat transfer, boiling and flow rate. Influence of alloying elements such as nickel, iron, silicon or copper. Probable mechanism of grain boundary accelerated and uniform types of attack. Weldability and mechanical properties of corrosion resistant aluminum alloys. 21 references.—RML. 18578

6.6 Non-Metallic Materials

6.6.6, 8.4.5, 4.6.1, 3.5.4

Durability of Some Silicate Glasses that Could be Used in Fission Product Disposal. R. W. Durham and D. Bell. August, 1958, 31 pp. Available from Atomic Energy of Canada Ltd., Chalk River, Ontario, Canada. (CRDC-841; AECL-817).

Corrosion by water of glass made by fusing nepheline syenite with various fluxing agents has been investigated. The objective is to obtain a workable glass that would incorporate waste fission products and have a high resistance to attack by water. Glass of composition 15 wt.% calcium oxide, 85 wt.% nepheline syenite, has been found to have a corrosion rate of 2×10^{-8} g glass/cm^2-day at room temperature after the first few days of water contact. The effect of pH on the corrosion rate has been investigated and also the selective leaching of cations of different valency.—(auth.)—NSA. 18831

6.6.8

Plastics for Protection Against Corrosion. A. C. Docherty and H. Hughes. Chem. and Ind., No. 38, 1171-1179 (1959) Sept. 19.

Paper outlines the various ways in which plastics are used, especially in the chemical industry, for protection against corrosion.—BTR. 19098

6.6.6, 3.5.3, 8.4.3, 5.4.3

Erosion Resistance of Ceramic Materials for Petroleum Refinery Applications. C. R. Venable, Jr. Paper before Am. Ceramic Soc., 60th Annual Mtg., Pittsburgh, April 28, 1958. Am. Ceram. Soc. Bull., **38,** No. 7, 363-368 (1959) July.

Properties of 7 types of ceramic materials (including ceramic coating on steel) having potential applications as erosion-resistant linings in refinery equipment were investigated. Most suitable, in order of decreasing erosion resistance, are: SiC shapes, "phostab" mixes, ramming mixes, and refractory concretes. Erosion resistances were determined using fluid catalytic cracking catalyst in Lesar and McGee sand-blast apparatus. Effects of water content and curing procedure on erosion resistance and related properties were investigated. Practical applications and limitations of ceramic materials in fluid catalytic cracking units are discussed. Tables, graphs, 15 references.—INCO. 18587

6.6.4, 3.5.9

Development and Evaluation of Materials for High Temperature Applications. Period Covered February 1, 1958 through January 31, 1959. Charles E. Shulze, Frank A. Saulino, William T. Adams, Gustave E. Mangsen, James C. Andersen and Howard W. Emmons. Carborundum Co. U. S. Wright Air Development Center, Technical Rept. 59-10 (Pt I), March, 1959, 58 pp.

Various preparational techniques have been used to fabricate graphite-based bodies which have potential resistance to high-velocity, high-temperature air. Materials have been evaluated in a high-intensity arc testing facility. Results are reported. At least ten compositions have been developed which are superior to either AGKSP graphite or to a graphite-silicon carbide body on the bases of tests imposed. (auth.)—NSA. 18617

6.6.5, 4.6.11

Influence of Sea Water on Corrosion of Reinforcement. R. Shalon and M. Rafael. J. American Concrete Inst., **30,** (ACI Proc., **55**), No. 12, 1251-1268 (1959) June.

Alkalinity of air-exposed concrete was found insufficient for corrosion inhibition of reinforcements. Sea water used for mixing of air-exposed reinforced structures makes the reinforcement highly vulnerable to corrosion. Adequate surface covering and depth of cover or special surface treatment is suggested.—RML. 18628

6.6.4, 3.5.4, 8.4.5

Comparison of Data on the Oxidation of Graphite in Reactors. M. Tomlinson. United Kingdom Atomic Energy Authority, Res. Group, Atomic Energy Research Establishment (C/R-2619), Harwell, Berks, England, April, 1959, 21 pp. Available from British Information Service, 45 Rockefeller Plaza, New York, N. Y.

Various reported values for the rate of oxidation of reactor-grade graphite when irradiated in air in a reactor at normal operating temperatures (60 to 200 C) show seemingly wide discrepancies, i.e., oxidation rates ranging from 0.024 to 4.5% graphite weight loss per 10^{20} neutrons/cm^2. It is shown how these apparent discrepancies can be reconciled in terms of the reaction scheme proposed. The apparent discrepancies arise because the oxidation rate is critically dependent upon the geometry of the system and the gas flow rate, in addition to the more obvious parameters. In the investigations considered, the gas flow rates covered a 2,000 fold range and this is the main reason for the difference in the observed oxidation rates. (auth.)—NSA. 18629

6.6.8, 4.3.2, 7.2

Reinforced Epoxy Resin Pipe Resists Corrosives Above 150 F. G. Weyermuller. Chem. Processing, **22,** No. 2, 115-116 (1959) Feb.

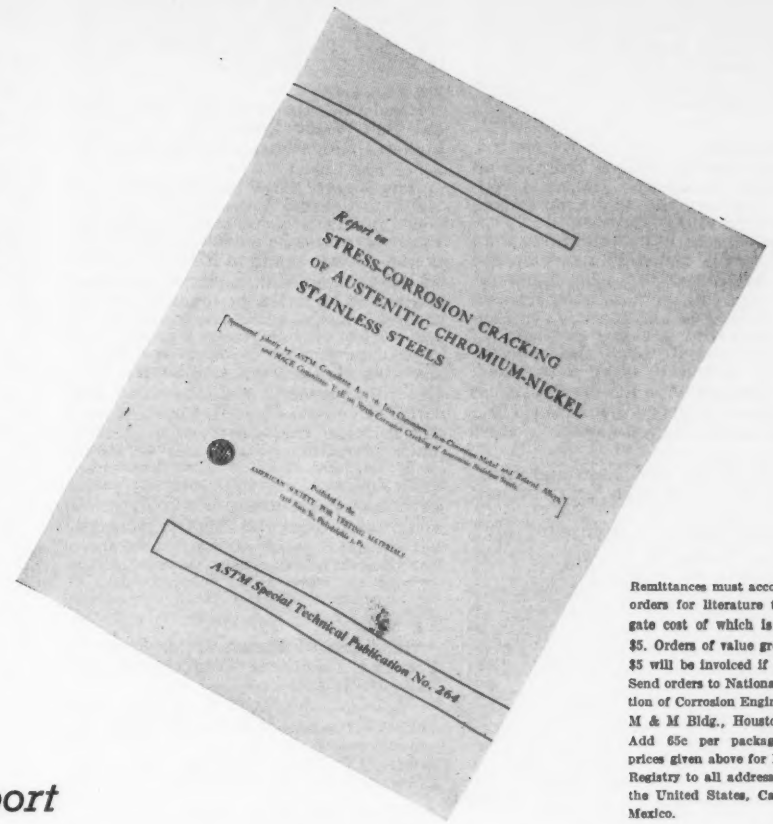
Metal and lined piping handling sulfuric acid at temperature above 150 F was replaced with Fibercast pipe at Industrial Rayon plant where Tyrex viscose tire cord is produced. Pipe is made

Also Available

STRESS CORROSION CRACKING

Fifteen articles from CORROSION on various aspects of high temperature, and ambient temperature sulfide stress corrosion cracking.

Per Copy $5.00



Remittances must accompany all orders for literature the aggregate cost of which is less than $5. Orders of value greater than $5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65c per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

ASTM-NACE Report

★

STRESS-CORROSION CRACKING OF AUSTENITIC CHROMIUM-NICKEL STAINLESS STEELS

★

ASTM Special Technical Publication No. 264

★

A report sponsored jointly by the American Society for Testing Materials Committee A-10 on Iron-Chromium, Iron-Nickel and Related Alloys and NACE Unit Committee T-5E on Stress-Corrosion Cracking of Austenitic Stainless Steels. The 92-page, 8¼x11 inch booklet is divided into two parts. Part I consists of a review and discussion of 129 case histories from 25 sources experiencing stress-corrosion cracking of austenitic stainless steels. Part II covers information on current research activity and a review of present knowledge of the basic mechanism.

There is a comprehensive bibliography and abstracts covering years 1935-59.

NACE, ASTM Members, per copy $4.80
Non-Members, per copy $6.00

NATIONAL ASSOCIATION of CORROSION ENGINEERS
1061 M & M Bldg. Houston 2, Texas

11a

by bringing woven glass fibers and epoxy resin together in high-speed centrifugal casting machine. It withstands temperatures as high as 300 F, up to 1000 psi pressure, has same linear coefficient of expansion as steel, is nonconductor and not subject to cold flow. —INCO. 18649

6.6.9, 3.4.6, 3.5.9

Thermal and Oxidative Degradation of Silicones. Luciano C. Scala and William M. Hickam. Ind. and Eng. Chem., **50,** 1583-1584 (1958) October.

Variously substituted silicones were exposed to the action of oxygen and heat to investigate the degradation reactions occurring at high temperatures in the presence of air. The rates of oxygen absorption by, and evolution of gases from methyl-, vinyl-, and phenyl-containing silicones were determined. Phenyl silicones were the most resistant to oxidation, followed by methyl- and vinyl-substituted silicones.—BTR. 17695

6.6.9, 3.4.6, 3.8.4

Kinetics of the Oxidation and Nitridation of Silicon at High Temperatures. J. W. Evans and S. K. Chatterji. J. Phys. Chem., **62,** No. 9, 1064-1067 (1958).

Kinetic behavior of silicon in oxygen, CO_2, nitrogen and (A + 0.2% vol. N) was determined at 1200-1400 C by means of a thermobalance. In oxygen and CO_2 the rate laws were parabolic with activation energies of 43 and 32 kcal/g.mol., respectively. Erratic behavior was observed in pure nitrogen owing to the formation of a volatile nitride (possibly Si_2N_3) but at low partial pressures of nitrogen volatilization was absent (possibly by repression of the reaction $6Si_2N_3 \rightleftarrows 4Si_3N_4 + N_2$) and a logarithmic rate law held.—MA. 18102

6.6.9, 3.8.4

Factors Determining the Oxygen Content of Liquid Silicon at Its Melting Point. W. Kaiser and J. Breslin. J. Applied Physics, **29,** No. 9, 1292-1294 (1958).

Oxygen content of liquid silicon is shown to increase proportionally to the oxygen content of the ambient helium-oxygen mixture for oxygen partial pressures, $p_o < 8$ mm mercury, during the growth of silicon crystals from the melt. This is explained by the proportionality between the p_o in the ambient gas and the silicon dioxide partial pressure on the surface of the liquid silicon. For $p_o > 8$ mm mercury the melt is covered by a film of silicon dioxide and a saturated value of $\sim 2 \times 10^{18}$ 0 atoms/cc is observed in the grown crystal.—MA. 18055

7. EQUIPMENT

7.2 Valves, Pipes and Meters

7.2, 3.5.8, 5.4.3, 8.9.3

Corrosion of Buried Piping 202-S Building. K. K. Campbell. General Electric Co. Hanford Atomics Products Operation. U. S. Atomic Energy Comm. Pubn., HW-57733, October 17, 1958, 28 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

An investigation was made to determine the cause of the leaks in the stream lines, as well as to develop a possible method of stopping or retarding future failures, and also to develop a method of repairing those lines which have failed. The pipes failed due to stress-corrosion aided by chloride ion. Tests were conducted on the practicability of repairing the damaged pipe lines by installing a plastic tube lining the full length of the pipe.—NSA. 18047

7.2, 4.6.3, 8.4.3

Resilient-Seated Butterfly Valves Resist Salt-Water Corrosion. G. Weyermuller. Chem. Processing, **22,** No. 6, 82-84 (1959) June.

Large gate valve handling brackish water for Creole Petroleum Corp. corroded rapidly in a number of cases, basic cause of trouble being electrolysis. Temporary repairs made to interior of some of these valves with a plastic protective coating were not a permanent solution to problem. Use of an alloy trim to better withstand corrosion ups cost and desired performance still is not always obtained. To achieve satisfactory service with economy, resilient-seated butterfly valves were installed in company's $28 million gas conservation plant at Lake Maracaibo. Plant uses 28 valves of 8" size and 38 of 10" size. Bodies are malleable iron, cadmium-plated. Valves have aluminum-bronze disc, Type 316 stem, and brass bushings. Butterfly valves have performed satisfactorily handling brackish water since placed in service in June 1957. Photos.—INCO. 18659

7.2, 5.2.1

Corrosion of Buried Metal Pipe. (In French.) l'Industrie Française, **8,** 257-261 (1959) March.

Chemical, biochemical and electrochemical corrosion of metal pipes conveying water, vapor, gas, oil and other fluids. Cathodic protection and other preventive measures.—RML. 18480

7.2, 8.4.5, 6.2.5, 6.3.4, 6.6.6

Further Evaluation of Check Valve Material for the Homogeneous Reactor Program. R. Blumberg. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-59-8-135, August 4, 1959, 14 pp. Available from Office of Technical Services, Washington, D. C.

A number of materials were tested to improve check valve trim material selection for aqueous homogeneous system fluids. Previous recommendations of Stellite 3 and 17-4 PH stainless steel were found valid for uranyl sulfate and distilled water service, respectively. Aluminum oxide and boron carbide were found applicable to ThO_2 slurry service. Test runs demonstrate that check valve hardware is now available to pump slurry for at least 3 months of continuous duty. (auth)—NSA. 19658

7.5 Containers

7.3, 5.2.3, 8.9.5

Model Experiment for Cathodic Protection of Propeller and Propeller Shaft. (In Japanese.) Hideo Kada, Tokizo Miyajima and Yutaka Morita. Corrosion Engineering, **8,** No. 4, 8-10 (1959) April.

In case of adopting cathodic protection, always it is necessary to connect with a circuit of high conductivity between anode and cathode. While, in the electric circuit between ship's hull and propeller shaft, high electric resistance is inserted due to lubricating oil film at running ship (this fact has been proved by the measurements at several ships), and so the effect of cathodic protection is extremely decreased.

To increase the effect, the resistance of oil film must be diminished by other circuit.

This paper reports the result of experiment by our model of propeller and propeller shaft concerning these problems. 17621

7.3, 3.5.3, 3.2.2

Longer Life for Centrifugal Pumps . . . Cause and Cure of Cavitation and Corrosion. N. B. Heaps. Chem. Eng., **66,** No. 9, 156, 158, 160 (1959) May 4.

Corrosion first etches entire surface uniformly, disturbing fluid flow and causing large irregularities. Cavitation-corrosion comes from combined effect of high velocity, lowered pressure and corrosiveness of fluid. Result is pitting to various depths and sharp edges—especially at points of highest velocity. Corrosion is controlled in centrifugal pumps by usual methods (coatings, cathodic protection, etc.) but cure is proper material selection. Cavitation is eliminated by increasing pressure within pump by: increasing suction pressure, increasing suction-pipe diameter, decreasing suction-pipe length, and reducing flow by throttling discharge. Photographs.—INCO. 18455

7.3, 8.9.5, 5.2.1, 3.6.6

Marine Corrosion of Propeller Shafts. A. J. Maurin. Tech. et applications pétrole, **14,** No. 158, 6419-6424, 6426-6427, 6473 (1959) March. (In French.)

REDIC cathodic protection system is designed to mitigate corrosion of tankers and other ships resulting from establishment of electrochemical couples between the propeller, propeller shaft and/or hull. The electrochemical mechanism of this type of corrosion and the principles underlying the REDIC system are discussed at length. 18425

7.3, 6.3.6

Prevention of "Wastage." A. R. French. Corrosion prevention and Control, **5,** No. 12, 45-46 (1958) Dec.

Excessive wastage of marine propellers is described. Although its cause remains unknown, alloys of copper-manganese-aluminum (Novoston) were developed which are resistant. Some mechanical properties and other uses of these alloys are described.—MA. 18760

7.6 Unit Process Equipment

7.6.3, 6.2.5, 3.7.3, 3.5.8

Investigation of Cracks in an 18/13/1 Stainless-Steel Autoclave. F. Turner and H. K. Richardson. United Kingdom Atomic Energy Authority. Industrial Group. Culcheth Labs. Culcheth, Lancs, England. IGR-TN/C-1015, 1958, 11 pp. A stainless steel autoclave used in the corrosion testing of metals in water failed by stress corrosion in the vicinity of a weld. Welding has been by metallic arc using flux-coated electrodes and a slag deposit was found at the weld root in the failed area. The flux and resultant slag deposit were proved to contain significant amounts of chloride. The slag deposit was connected with the autoclave interior via the interface between the base plug and wall. This provided the corroding medium which in the presence of water and residual plus operating stresses caused failure by stress-corrosion cracking. Recommendations are made for the avoidance of this type of failure. (auth)—NSA. 18969

7.6.4, 4.2.3, 4.4.7, 6.2.5, 3.5.9

Fire Side Corrosion in Oil-Fired Boilers. L. K. Rendle, R. D. Wilsdon and

G. Whittingham. Paper before 5th World Petroleum Conf., New York, 1959. Combustion, **31**, No. 2, 30-42 (1959) Aug.

First part deals with assessment of various superheater steels and heat resistant alloys in respect to high temperature corrosion by combustion of low and high vanadium fuel oils. Role of vanadium was specifically studied. Superheater steels investigated were: 18 chromium-11 nickel-niobium, 17.5 chromium-11 nickel-niobium, 13.5 chromium and 2¼ chromium-1 molybdenum. Heat resisting alloys were: 20 chromium-7 nickel, 25 chromium-20 nickel, 60 nickel-12 chromium, 25 chromium-12 nickel and 53 nickel-18 chromium. Weight loss and scale analysis data are given. Microstructure of materials is discussed; sigma phase was observed in some of the heat resisting alloys. Experiences with dolomite injections are reported. Second part reviews results of full scale and pilot scale investigations of low temperature corrosion, providing information on degree of formation of sulfuric acid in oil-fired boilers and efficacy of operational conditions and control by use of additives including ammonia. Tables, graphs, diagrams of furnaces and boilers. 26 references.—INCO. 18523

7.6.4, 4.2.3

Corrosion and Soot Emission in Oil Fired Power Plants in Relation to the Formation of SO_3. (In Italian.) G. F. T. Murray. Britannica Petrol. S.p.A. Riv. Combustibili, **13**, 319-346 (1959) May.

Use of ammonia as additive against boiler corrosion is described based on 3 actual cases, which are: a boiler furnishing 68,000 kg/hr of steam with an economizer and a rotating air preheater; a "La Mont" boiler furnishing 45,000 kg/hr of steam and having a tubular air preheater; and a marine boiler. The factors causing low-temperature corrosion such as fuel oil constituents and operating conditions are reviewed. 12 references. 18439

7.6.8, 8.4.3

Chemical-Technological Methods for Combating the Corrosion of Low-Temperature Equipment in Atmospheric-Vacuum Disillation Units. (In Russian.) L. D. Zakharochkin, S. I. Vol'fson and L. G. Klochkova. Khim. i. Technol. Topliva (Chem. & Technol. of Fuels), **4**, No. 3, 46-52 (1959) Mar.

Data are presented on 2160-hr. corrosion tests in condensers and pump discharge lines for unstabilized gasoline distillate in distillation units in a U.S.S.R. refinery which handles sulfur-bearing crude. The rapid corrosion is caused by incompletely removed salts. During distillation at 350 C, no hydrolysis of sodium chloride takes place, but 3.5-10% of the calcium chloride is hydrolyzed and hydrolysis of magnesium chloride reaches 35-50%. Corrosion may be suppressed by adding an aqueous mixture of caustic and calcined soda. 18719

7.6.5, 6.2.5, 6.3.15, 8.4.5

Corrosion Studies Concerning the Redox F-2 and D-14 Concentrators—Phase II Operation. N. D. Groves, M. C. Fraser and W. L. Walker. General Electric Co. Hanford Atomic Products Operation, U. S. Atomic Energy Commission Pubn., HW-38610 (Del.), April 30, 1956 (Declassified with deletions Feb. 3, 1959), 18 pp. Available from Office of Technical Services, Washington, D. C.

A laboratory investigation of the potential corrosion problems incurred by the process changes was deemed necessary to provide a basis for estimating the expected service life of the Redox F-2 and D-14 concentrators. The three fold purpose of this laboratory study was to: establish the order of magnitude of the corrosion problem existing in the Redox F-2 and D-14 concentrators, provide preliminary indications of the most suitable material of construction for the replacement of these vessels, and indicate which area of investigation has the greatest potential for solving these corrosion problems. Samples of types 304L, 312, 347 stainless steels were exposed in the sensitized and as-welded conditions to synthetic anticipated Redox process solutions, both as heat transfer surfaces and as static total immersion specimens. Samples of Grade A-55 titanium were similarly exposed. The corrosion rates determined by these experiments indicate, a severe corrosion problem potentially exists in the Redox F-2 and D-14 concentrators, titanium exhibits corrosion rates two orders of magnitude less than the stainless steels tested, Type 304L stainless steel welded with Type 308L welding alloy exhibit the greatest corrosion resistance of the stainless steels tested, and solution composition has a greater effect on the corrosion rate than the differences between the stainless steels. (auth)—NSA. 19184

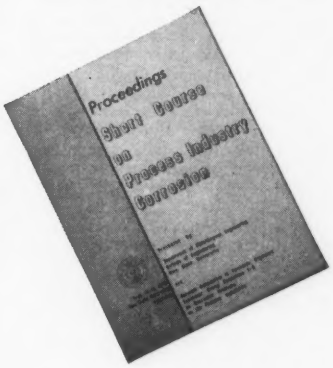
8. INDUSTRIES

8.4 Group 4

8.4.3

How Phillips Solved Six Gas Plant Corrosion Problems. J. S. Conners and C. L. Seyer. Paper before Am. Petroleum Inst., Refining Division Mtg., Los Angeles, May 12, 1958. Petroleum Refiner, **37**, No. 5, 177-182 (1958) May.

Practical aspects of 6 commonly occuring corrosion problems including remedy for each. In aqueous amine treaters, stress corrosion cracking of carbon steel still kettle shells necessitated their removal, stress-relief and reinstallment. Severe pitting of amine bubble caps of Type 410 resulted in replacement of 50% of all bubble caps. Experiments are under way on heavy, cast iron and thin, Type 316 caps. Corrosion in steam and steam-condensate system was reduced by addition of blend of neutralizing amines to boiler feedwater. Solution to corrosion of hydrocarbon coil piping in cooling tower was to apply inorganic zinc-dust coating. Water distribution piping in cooling tower was changed from steel to rigid polyethylene. In butane isomerization units, aluminum chloride catalyst is greatly activated by addition of anhydrous hydrochloric acid. Average life of steel pipe in corrosive portion of unit is 3 years. Glassed-steel vessels are being considered for replacement of concrete-lined vessels. Seamless steel tubes originally used in effluent condensers were replaced with Monel tubes, and design of condensers was changed to utilize Monel-faced double-tube sheets. In gas transfer lines, injection of inhibitor (salt of imidazoline and high molecular-weight organic acid) resulted in reduction of corrosion. Condensation of water on inside surfaces is primary cause of internal corrosion of cone-roof tanks. Floating-roof storage tanks are subject to metal loss on shell due to abrasive action of roof seal shoes. Zinc-dust coating is providing 2-3 years of protection on cone-roof tanks. Cathodic



Proceedings

SHORT COURSE

on

PROCESS INDUSTRY CORROSION

Twenty papers presented Sept. 12-16 at the symposium sponsored jointly by Ohio State University and NACE Technical Group Committee T-5 on Corrosion Problems in the Process Industries. The 450-page book measures 8½ x 11 inches, has a plastic back, flat opening. Many tables, graphs and illustrations; hundreds of references.

Add 65¢ per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

PER COPY U.S., CANADA and MEXICO

$20 NACE Members

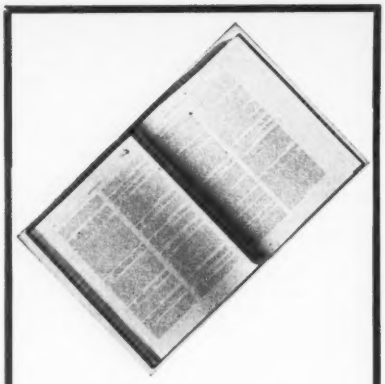
$25 Non-Members

These papers are by engineers concerned with controlling corrosion in some of the nation's largest chemical processing plants. Considered are use of metal and plastic materials in a wide variety of environments, including most of the common acids and alkalis; special problems found in both low and high temperature processes, corrosion measurements, coatings, design and other practical information.

Send Orders and Remittances to

National Association of Corrosion Engineers

1061 M & M Bldg. Houston 2 Texas



Your key to more than 4287 technical articles and books on corrosion control

•

1954-1955

BIBLIOGRAPHIC SURVEY of CORROSION

NACE Members . $15.00

Non-Members . . $20.00

Topically indexed and cross-indexed according to the NACE Abstract Filing System. Alphabetical author index. Alphabetical subject index. 468 pages 8½ x 11 inches, hard cloth binding.

1952-53 volume, containing 3300 abstracts, NACE members $10
(Non-members $12.50)

1950-51 volume, containing 4454 abstracts, NACE members $10
(Non-members $12.50)

1948-1949 volume, containing 3512 abstracts, NACE members $10
(Non-members $12.50)

1946-1947 volume, containing 3362 abstracts, NACE members . . . . . $ 7
(Non-members $9)

1945 volume, containing 1086 abstracts, NACE members . . . . . $ 4
(Non-members $5)

Buy More Than One Volume and Save 10%

• Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount of U. S. funds.

• In addition to the prices shown there is a charge of $.65 per package for sending volumes by registered book post to addresses outside the United States, Canada and Mexico.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg. Houston 2, Texas

protection is providing complete protection against external corrosion of tank bottoms.—INCO. 18836

8.4.5

Corrosion Problems in Gas Cooled Reactors. (In French.) R. Darras. Bull. inform. sci. et tech., No. 21, 13-25 (1958) Sept. English Translation by P. J. Robinson, United Kingdom Atomic Energy Authority, on deposit at the Depository Libraries [IGIS-8(RD/W)].

Corrosion behavior of different materials used in gas-cooled reactors is reviewed. A brief report is made on the dry oxidation of metals and the methods of investigation. The materials studied are the nuclear fuels (uranium and its compounds), canning materials (magnesium, aluminum, zirconium and beryllium and their alloys and stainless steel), and moderators (graphite and beryllium oxide). An attempt is made to specify the temperature limits for each material in various gases. The possibilities of improving the energy yield of gas cooled reactors by the use of more refractory materials or the use of other gases is discussed. 38 references. (auth.)—NSA. 18829

8.4.5, 3.5.4, 6.4.2

Behaviour of Al-Ni Sheathing on UO_2 Fuel Elements Irradiated in High Temperature Water (X-2h Test). F. H. Krenz and A. E. Hunton. November, 1958, 75 pp. Available from Atomic Energy of Canada, Ltd., Chalk River, Ontario, Canada (CRMet-806; AECL-758).

Methods have been developed for the fabrication of fuel elements consisting of uranium dioxide pellets sheathed in aluminum-nickel alloy tubing. Corrosion resistant end-enclosures were made by hot pressure welding. The corrosion behavior of these elements has been determined in an exposure for two reactor cycles in the X-2 loop in NRX Reactor. Loop conditions were: deionized water at 280 C flowing at 18 ft/sec over the fuel sheaths. Heat fluxes through the sheaths varied from 11.4 to 68.5 watts-cm². The corrosion of the sheaths in this exposure was severe. A penetration of roughly 7 x 10^{-3} inches was measured after the first reactor cycle (21 days). The penetration was much less during the second cycle for moderately rated elements (11-12 watts/cm²) but again about 7 x 10^{-3} inches for a highly rated element (68.4 watts/cm²). It could be concluded that an increased heat flux resulted in an increased rate of sheath penetration, the increase from ~12 watts/cm² to ~70 watts/cm² approximately doubling the penetration. It is now known that the corrosion observed in this experiment was more severe than would have been found in a system containing a much larger area of corroding aluminum. The severe pitting and erosion of the X-2(h) samples are known to be characteristics of corrosion in a system containing a small area of aluminum in a large volume of purified water. The X-2(h) test was therefore not typical of conditions in a reactor with aluminum-nickel sheathed fuel. (auth.)—NSA. 18859

8.4.3, 4.3.4

Reduce Fuel-Gas-Line Corrosion. L. Resen. Oil & Gas J., **56**, No. 44, 107, 109 (1958) Nov. 3.

Experience gained at Pure Oil Co.'s Nederland, Tex. refinery. When refinery offgases are used for fuel systems, an inherent problem is the fouling caused by chemical compounds carried in the gases. These include free sulfur, iron sulfide, and more recently, ammonium chloride and hydrochloric acid. Hydrochloric acid from the catalytic reforming unit offgas combines with ammonia in offgas from other units to give more ammonium chloride. Chemicals will foul pressure regulators, heater firing valves, and heater-burner orifice tips. Partial plugging of burners tends to give uneven unsatisfactory firing conditions. Methods suggested to minimize fouling and its effects are use of water injection to combat ammonium chloride in cat reformer offgas and design of fuel-gas takeoffs to minimize picking up contaminants. Photos.—INCO. 18933

8.4.5

HRP Dynamic Corrosion Studies (In-Pile Development). Summary of Runs HT-20, HT-21 and HT-22 (Thorium Oxide Slurry). D. W. Hubbard. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-58-4-48, April 15, 1958, 13 pp. Available from Office of Technical Services, Washington, D. C.

Homogeneous reactor program runs HT-20, HT-21 and HT-22 are described. These runs were made to determine the handling characteristics of a slurry containing thoria calcined at 1600 C and to evaluate the operation of the 5-gpm slurry pump. The experimental procedures are described. It was concluded that 1600 C calcined 0.7 μ mean particle size thoria can be satisfactorily circulated using the 5-gpm pump.—NSA. 18737

8.4.5

Water Decomposition in a Direct-Cycle Boiling Water Reactor Increases Corrosion Rate. A. P. Gavin, C. R. Breden, R. E. Bailey, M. H. Theys and G. E. Goring. Argonne National Lab. Ind. Eng. Chem., **51**, 1265-1266 (1959) Oct.

Water decomposition in the Experimental Boiling Water Reactor decreased slightly upon the addition of hydrazine (~3 ppm.) The need for a catalytic recombiner for dissociated water in the exhaust stream from air ejectors resulted in the use of platinized alumina pellets. The system comprises a flowmeter to monitor the supply of diluent stream, temperature and pressure safety switches, and air operated valves designed to by-pass the recombiner unit in the event of unsafe conditions. The entire operation is by remote control and hydrogen recombination is 99% complete. Corrosion analyses of the oxide films on fuel plates that have been handled give a composition of 36% aluminum, 11% nickel and 3.7% iron. Major activity during operation is due to nitrogen-16, formed by (n,p) reactions between fast neutrons and oxygen-16. Other activity present is from the formation of sodium-24, cobalt-58 and cobalt-60. Decontamination consists of flushing the connections with water until the radioactivity level is within tolerance levels.—NSA. 19143

8.4.5, 3.4.3

Activation and Transport of Long-Lived Corrosion Products. Section I. Fourth, Fifth, Sixth, Seventh and Eighth Performances. Duquesne Light Co. U. S. Atomic Energy Commission Pubn., AECU-4197, April 28, 1959, 10 pp. Available from Office of Technical Services, Washington, D. C.

Mechanisms of activation and transport of corrosion products under the

reference water conditions of the Shippingport Pressurized Water Reactor are discussed. (auth.)—NSA. 19086

8.4.5, 6.2.5

Improved Bolting Materials for Internal Assembly of HRP Components. B. D. Draper. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-59-10-69, October 1, 1959, 10 pp. Available from Office of Technical Services, Washington, D. C.

An investigation was made to improve materials and practices used in the internal bolting of HRP components. Wire type stainless steel thread inserts were found to be corrosion resistant and non-galling, although somewhat difficult to install and remove. These operations are especially troublesome if done remotely. Two alloys were found to be corrosion-resistant, non-galling and of high strength: CD4MCu and Uniloy 19-9 DL. Other promising alloys, which however require additional testing, are AM-355, Timken 16-25-6 and Timken 16-15-6. (auth.)—NSA. 19079

8.9 Group 9

8.9.3, 5.4.10, 5.2.1

Pipeline Protection in the Middle East. Part I. Protective Coating and Cathodic Protection Practice. L. R. Sparrow. Corrosion Technology, **6,** No. 1, 13-18 (1959) Jan.

Discusses practical considerations and difficulties in applying both coating and cathodic protection. Small diameter pipelines can be lifted and coated without interruption in oil flow. Larger pipes (>40 cm diam) must be laid coated with tough, electrically resistant and waterproof material and placed under cathodic protection throughout their entire length. Problems encountered and protection provided for conditions such as salt marshes, sand dunes, annual rainfall and floods, and seepage of hydrogen sulfide-containing gases, are discussed. Protective materials used include Fibreglas reinforcement, Kraft outer wrapping paper, adhesive polyvinyl chloride tape and epoxy/coal tar coatings. Map, photos.—INCO. 18551

8.9.5, 4.4.6, 5.8.2, 5.2.1, 5.7.4

Protection Against Corrosion in Light-Oil Tank Ships. (In German.) R. H. Maass and R. D. Merrick. Paper before European Corrosion Federation, 2nd Congress, Frankfurt, June 7, 1958. Werkstoffe u. Korrosion, **10,** No. 5, 305-311 (1959) May.

Refined light oils cause greater corrosion damage in tankers than do crude oils. Survey is presented of protective methods for light oil tankers as developed by Esso. Preventive measures investigated include: films-formed by water- and oil-soluble inhibitors, paints, cathodic protection, dehumidification, and use of low alloy steels. Nickel steels are among those being tested. Economics of various measures are evaluated. Tables, graphs.—INCO. 18415

8.9.3

Study of Corrosive Attack on Underground Pipelines. G. Eingrieber. Gas-u. Wasserfach, **100,** No. 7, 157-161 (1959) Feb. 13.

A discussion on the electrochemical corrosion of underground pipelines includes Seismos G.m.g.H.'s method for testing metal pipelines for insulation defects and corrosion damage. 19110

8.9.4

Corrosion in Railway Engineering. Pt. I. H. Johns. Corrosion Prevention and Control, **5,** No. 10, 51-52 (1958).

Some aspects of corrosion in railway engineering and pretreatment of surfaces before painting are briefly described.—RPI. 19238

8.9.5, 4.6.7, 4.6.11, 5.4.5, 5.3.2

Protection of Construction Material for Shipbuilding. (In Serbo-Croat with English Summary). B. Vajagic. Zastita Materijala (Protection of Material), **7,** No. 1, 5-9 (1959) Jan.

This article gives details of types of steel used in shipbuilding and the protection against corrosion of boats in fresh-and-sea-water, also details of light metals and wood used in their construction. Protection above water level is by means of paint based on zinc oxide and linseed oil. Metallic protection is often necessary, using zinc, cadmium, etc. A water tank is coated internally with aluminum followed by zinc. Zinc anodes of 99.99% purity are installed at the stern. —RPI. 18586

TECHNICAL REPORTS

on

Corrosion in Oil and Gas Well Equipment

T-1A Survey of Corrosion Control in California Pumping Wells. A Report of T-1A on Corrosion in Oil and Gas Well Equipment, Los Angeles Area. Pub. 54-7. Per Copy $1.50.

TP-1 Report on Field Testing of 32 Alloys in the Flow Streams of Seven Condensate Wells (Pub. 50-3) NACE members, $8; Nonmembers, $10 per Copy.

T-1B-1 Well Completion and Corrosion Control of High Pressure Gas Wells—A Status Report of NACE Task Group T-1B-1 on High Pressure Well Completion and Corrosion Mitigation Procedure. Pub. 59-6. Per Copy $1.50.

T-1C Current Status of Corrosion Mitigation Knowledge on Sweet Oil Wells. A Report of Technical Unit Committee T-1C on Sweet Oil Well Corrosion. Per Copy, $1.50.

T-1C Field Practices for Controlling Water Dependent Sweet Oil Well Corrosion. A Report of Technical Unit Committee T-1C on Sweet Oil Well Corrosion, Compiled by Task Group T-1C-1 on Field Practices. Pub. No. 56-3. Per Copy $1.50.

T-1C Status of Downhole Corrosion in the East Texas Field—A Report of NACE Tech. Unit Committee T-1C on Sweet Oil Well Corrosion. Pub 57-23. Per Copy $1.50.

T-1C Water Dependent Sweet Oil Well Corrosion Laboratory Studies—Reports of NACE Tech Unit Committee T-1C on Sweet Oil Well Corrosion. Pub. 57-24, Per Copy $2.50.

T-1C Theoretical Aspects of Corrosion in Low Water Producing Sweet Oil Wells —A Status Report of NACE Tech. Unit Committee T-1C Prepared by Task Group T-1C-4. Pub. 58-4, Per Copy $1.50.

T-1C Experience With Sweet Oil Well Tubing Coated Internally With Plastic—A Status Report of Unit Committee T-1C on Sweet Oil Well Corrosion. Pub. 58-8, Per Copy $1.50.

TP-1D Sour Oil Well Corrosion. *Corrosion,* August, 1952, issue. $1.50 Per Copy.

TP-1G Field Experience With Cracking of High Strength Steel in Sour Gas and Oil Wells. (Included in Symposium on Sulfide Stress Corrosion.) (Pub. 52-3) NACE Members $3.50; Others $5.00 Per Copy.

T-1G Sulfide Corrosion Cracking of Oil Production Equipment. A Report of Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking. Pub. 54-5. $1.75 Per Copy.

T-1G Hydrogen Absorption, Embrittlement and Fracture of Steel. A Report on Sponsored Research on Hydrogen Sulfide Stress Corrosion Cracking carried on at Yale University, Supervised by NACE Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking by W. D. Robertson and Arnold E. Schuetz. Pub. 57-17. Per Copy $5.50.

T-1J Status Report of NACE Technical Unit Committee T-1J on Oil Field Structural Plastics. Per Copy $1.50.

T-1J Reports to Technical Unit Committee T-1J on Oilfield Structural Plastics. Part 1—Long-Term Creep of Pipe Extruded from Tenite Butyrate Plastics. Part 2, Structural Behavior of Unplasticized Geon Polyvinyl Chloride. Publication 55-7. Per Copy $2.75.

T-1J Summary of Data on Use of Structural Plastic Products in Oil Production. A Status Report of NACE Technical Unit Committee T-1J on Oilfield Structural Plastics. Per Copy $2.75.

T-1J Service Reports Given on Oil Field Plastic Pipe. Activities Report of T-1J on Oilfield Structural Plastics. Per Copy $1.75.

T-1J Oilfield Structural Plastics Test Data are given. Activities Report of T-1J on Oilfield Structural Plastics. Per Copy $1.75.

T-1J Reports to Technical Unit Committee T-1J on Oil Field Structural Plastics. Part 1—The Long-Term Strengths of Reinforced Plastics Determined by Creep Strengths. Part 2—Microscopic Examination as a Test Method for Reinforced Plastic Pipe. Per Copy $1.50.

T-1J Status Report of NACE Technical Unit Committee T-1J on Oil Field Structural Plastics. Part 1—Laboratory Testing of Glass-Plastic Laminates. Part 2—Service Experience of Glass Reinforced Plastic Tanks. Part 3—High Pressure Field Tests of Glass-Reinforced Plastic Pipe. Per Copy $1.50.

T-1J Service Experience of Glass Reinforced Plastic Tanks—Status Report of NACE Technical Unit Committee T-1J on Oil Field Structural Plastics. Pub. 57-18. Per Copy $1.50.

T-1J Experience with Oil Field Extruded Plastic Pipe in 1955—A Report of NACE Technical Unit Committee T-1J on Oil Field Structural Plastics. Pub. 57-19. Per Copy $1.50.

T-1K Proposed Standardized Laboratory Procedure for Screening Corrosion Inhibitors for Oil and Gas Wells. A Report of T-1K on Inhibitors for Oil and Gas Wells. Publication 55-2. Per Copy $1.50.

T-1K-1 A Proposed Standardized Static Laboratory Screening Test for Materials to be Used as Inhibitors in Sour Oil and Gas Wells. A Report of NACE Technical Unit Committee T-1K on Inhibitors for Oil and Gas Wells, Prepared by Task Group T-1K-1 on Sour Crude Inhibitor Evaluation. Publication 60-2. Per Copy $1.50.

T-1M Suggested Coating Specifications for Hot Application of Coal Tar Enamel for Marine Environment. A Report of NACE Technical Unit Committee T-1M on Corrosion of Oil & Gas Well Producing Equipment in Offshore Installations. Publication No. 57-8. Per Copy $1.50.

T-1M Suggested Painting Specifications for Marine Coatings. A Report of NACE Technical Unit Committee T-1M on Corrosion of Oil & Gas Well Producing Equipment in Offshore Installations. Publication No. 57-7. Per Copy 1.50.

Remittances must accompany all orders for literature the aggregate cost of which is less than $5. Orders of value greater than $5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65c per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

1061 M & M Bldg. Houston 2, Texas

NATIONAL ASSOCIATION of CORROSION ENGINEERS

Executive Offices: 1061 M & M Bldg., Houston 2, Texas

Telephone CApitol 4-6108

Executive Secretary ..... T. J. HULL

Assistant Secretary and Exhibition Manager ..... R. W. HUFF, JR.

Technical Committee Secretary ..... J. F. VANDER HENST, JR.

Administrative Assistant for Regions and Sections ..... G. A. ROLAK

Publication Director ..... NORMAN E. HAMNER

Editorial Assistant ..... DALE MILLER

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 1061 M & M Building, No. 1 Main Street, Houston 2, Texas.

•

The National Association of Corrosion Engineers is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of memberships, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Advertising and Editorial Offices of CORROSION

Address all correspondence concerning advertising, circulation and editorial matters relating to CORROSION to the NACE executive offices, 1061 M & M Building, Houston 2, Texas. Inquiries concerning and orders for reprints of technical information published in CORROSION should be sent to this address also.

OFFICERS and DIRECTORS

•

OFFICERS

President ..... GEORGE E. BEST
Manufacturing Chemists' Assoc., Inc., Washington, D. C.

Vice President ..... EDWARD C. GRECO
United Gas Corporation, Shreveport, La.

Treasurer ..... C. G. GRIBBLE
Metal Goods Corporation, Houston, Texas

Executive Secretary ..... T. J. HULL
1061 M & M Bldg., Houston, Texas

DIRECTORS

Past-President

HUGH P. GODARD 1960-61
Aluminium Laboratories, Ltd., Kingston, Ont., Canada

Representing Active Membership

R. McFARLAND, JR. 1958-61
Hills-McCanna Company, Chicago, Ill.

T. J. MAITLAND 1960-63
American Telephone & Telegraph Company, New York, N. Y.

J. P. BARRETT 1959-62
Pan American Petroleum Corp., Tulsa, Okla.

E. L. SIMONS 1959-62
General Electric Co., Schenectady, N. Y.

Representing Corporate Membership

L. W. GLEEKMAN 1960-61
Wyandotte Chemicals Corporation, Wyandotte, Mich.

L. C. WASSON 1958-61
A. O. Smith Corp., Milwaukee, Wis.

J. E. RENCH 1960-63
Napko Corporation, Houston, Texas

J. S. DORSEY 1960-63
Southern California Gas Co., Los Angeles, Cal.

GUY F. WILLIAMS 1959-62
Dowell Incorporated, Tulsa, Okla.

Representing Regional Divisions

E. H. TANDY ..... (Western) 1958-61
Standard Oil Co. of California, El Segundo, Cal.

A. B. SMITH ..... (Southeast) 1960-63
Amercoat Corp., Jacksonville, Fla.

J. D. BIRD ..... (Northeast) 1960-63
The Dampney Company, Hyde Park, Boston, Mass.

E. F. MOORMAN ..... (North Central) 1959-62
International Harvester Co., Chicago, Ill.

J. A. CALDWELL ..... (South Central) 1959-62
Humble Oil & Refining Co., Houston, Texas

T. R. B. WATSON ..... (Canadian) 1959-62
Corrosion Service Limited, Toronto, Ont., Canada

Directors Ex Officio

W. F. FAIR, Chairman Regional Management Committee
Tar Products Division, Koppers, Inc., Verona, Pa.

R. A. BRANNON, Chairman Policy and Planning Committee
Humble Pipe Line Co., Houston, Texas

R. S. TRESEDER, Chairman Publications Committee
Shell Development Co., Emeryville, Cal.

T. J. MAITLAND, Chairman Technical Practices Committee
American Telephone & Telegraph Co., New York, N. Y.

Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 17 January, 1961 No. 1

Accelerated Test Procedure For Evaluation Of Fiber Reinforced Resin Equipment In The Chemical Industry*

By ROBERT A. CASS* and OTTO H. FENNER*

Abstract

An account is given of the testing and evaluation procedures followed by a major chemical company in the selection of plastics for severe service. The use of the Instron Tensile Tester to furnish necessary physical properties change data, as a supplement to appearance, volume change, and percentage weight change data, is detailed. Various applications of plastic materials of construction under unusual or borderline environments are reviewed. Extensive data are reported on glass fiber reinforced epoxy resins percentage weight change vs flexural strengths with various plasticizers, and of glass fiber reinforced polyester resins percentage weight change vs flexural strength after exposure in such media as salicylic acid-sulfuric acid-water, 28 percent HCl, and maleic acid.

6.6.8, 2.3.7, 4.3.2, 4.4.2

Introduction

ONE OF THE more perplexing questions which confronts the average corrosion engineer in the selection of suitable materials of construction is that concerning plastics applications. No difficulties are experienced in deciding the inapplicability of a plastic under conditions in which it is readily attacked. However, this is not true in those cases in which very little visual change is apparent in the coupon or test section following an appreciable exposure period.

The major concern under these circumstances is whether some not readily apparent atack, or conditioning is occurring within the structure which might result in a serious failure of the piece of equipment at some future time. Should the plastic appear to be only mildly affected by the conditions to which it has been exposed, uncertainty may continue to exist as to its acceptability for long range applications. The present paper discusses the procedure employed by the J. F. Queeny Plant of the Monsanto Chemical Company in the evaluation of reinforced plastics as materials of construction for corrosive environments.

The most common approach to the examination of plastic materials after exposure is to first give them very extensive visual scrutinizations to determine any abnormal surface changes, color changes, softening or hardening, crazing, delaminating effects, exposures of fibers, or any other changes which may be indicative of a present or future failure. It is during this examination that the completely unacceptable materials are disclosed and eliminated from further considerations.

Usually the next step in the examination is a determination of any dimensional changes in the samples which show the degree of any detrimental swelling or shrinkage of the plastic materials. This is followed by a determination of the extent of any changes in weight of the test specimens. These weight changes are usually attributed to degradation of the resin through absorption of the environmental liquids, or by leaching of the resin or fiber through solvent or chemical attack. In most instances a single weight change at the completion of the test run is the only such check made. In many cases this lone weight loss determination would be satisfactory. However, in many more instances a false conclusion or inference may be obtained from this sole weight change determination. To avoid such possibilities it is advisable to run a series of weight and physical properties change evaluation on each specific plastic laminate at definite intervals of time during its exposure period. These points are then plotted, and from the slope of the curve and rate of change a more accurate picture is obtained of the performance of the plastic during exposure than is apparent from a single coupon evaluation. This procedure has resulted in a fairly satisfactory tool for use in the selection of reinforced plastic materials of construction.

An arbitrary rating system has been devised based upon the percentage weight change (PWC) and the changes in flexural strength of a plastic material of construction over a minimum exposure period of 600 hours. This method enables a fairly accurate estimation of the plastics probable future performance in the specific environment. This rating system not only is valuable for the prediction of the probable longevity of a particular reinforced resin system, but it has other added, desirable advantages. It is a way of expressing the rate of attack upon a particular plastic material in a manner which allows it to be compared with that of some other reinforced plastic being evaluated in the same environment. It permits a numerical value to be placed upon the plastic with a degree of precision which allows some means of clearly communicating the performance of each plastic. It is particularly worthwhile as a literature reference in comparing subsequent exposures, either of new construction materials in the same environments or of the specific plastic in different environments. The system as used requires some refinements before it will be an infallible, precise tool. Nevertheless, considered interpretation of the data as indicated from the PWC curves has been very beneficial in the selection of suitable plastic materials of construction.

Experimental Procedure

Figure 1 shows the performance of a particular glass fiber reinforced (GFR) polyester resin exposed to various plasticizers and esters. The evaluation was made to determine the suitability of both GFR polyester and epoxy resins as materials of construction for tanks in the storage of these products. Standard test coupons, consisting of a laminated plas-

TABLE 1—Plastics Rating System

Extrapolated Annual Percentage Weight Change (PWC) Range	Rating	Comments
−0.25% to +0.25%	Excellent (E)	No significant attack
−0.25% to −0.75% } +0.25% to +0.75% }	Good (G)	Acceptable as material of construction.
−0.75% to −1.50% } +0.75% to +1.50% }	Fair (F)	Inconclusive Danger apparent of delamination. Continue test for additional 600 hours, then re-evaluate.
−1.50% and +1.50%	Poor (P)	Generally proves unacceptable and shows incipient delamination.

★ Submitted for publication December 9, 1959. A paper presented at the 16th Annual Conference, National Association of Corrosion Engineers, Dallas, Texas, March 14-18, 1960.

* Monsanto Chemical Co., St. Louis, Missouri.

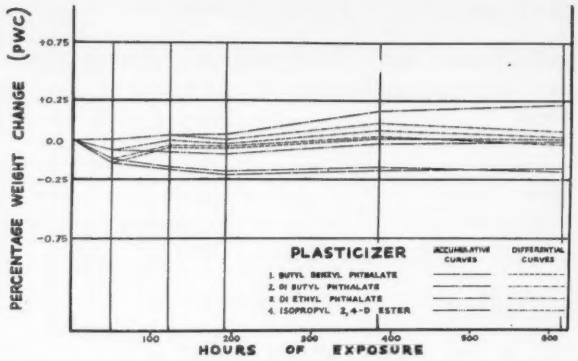


Figure 1—Performance of glass fiber reinforced polyester resin in four plasticizers and esters in the range 75-80 C.

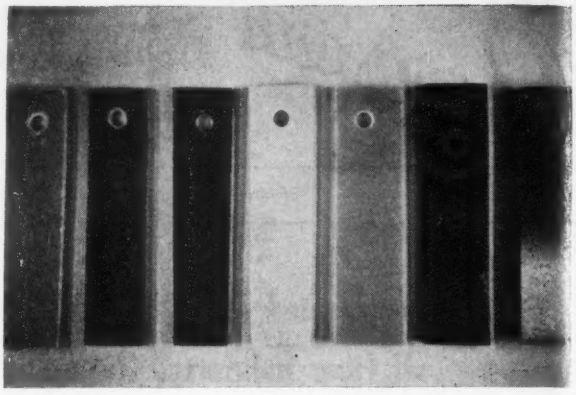


Figure 2—Standard test coupons.

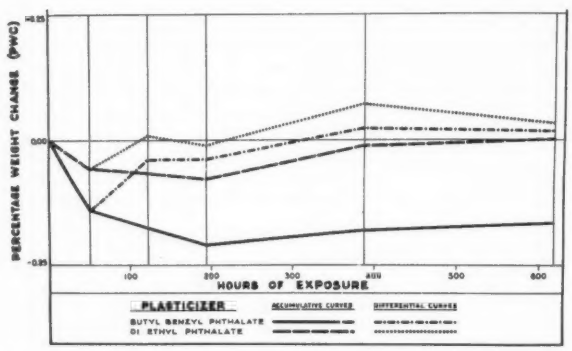


Figure 3—Performance of glass fiber reinforced polyester resin in various plasticizers and esters in the range 75-80 C.

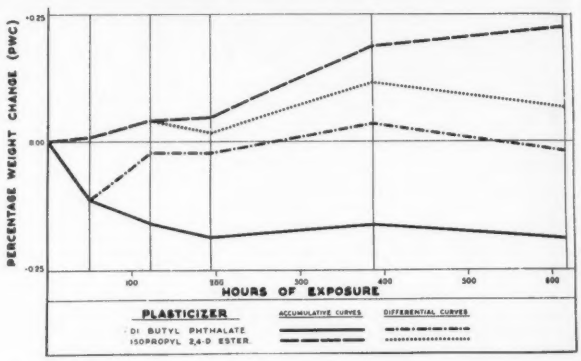


Figure 4—Performance of glass fiber reinforced polyester resin in various plasticizers and esters in the range 75-80 C. Plasticizers used were di butyl phthalate, isopropyl 2,4-D ester.

tic section, measuring approximately 1 inch wide x 4 inches long x ⅛ inch thick are usually employed. Several of these are shown in Figure 2. In those instances in which the changes in flexural strength with time are to be determined either larger coupons are installed and sections cut out of this mother coupon from time to time or several standard test coupons of the same material are included from the start. These test coupons are suspended in both the liquid and vapor phases whenever such conditions exist, or in an area of high velocity-erosion should it be practical to do so.

The main precaution to follow in the installation of the test coupon is that it be fastened securely in place. Many an hour of exposure has been nullified due to the fact that a loose coupon has been deformed or abraided under pounding against a wall of a pipe or tank in which it was suspended. Secondly, in any investigation in which plastic materials of construction are evaluated, care should be taken to make certain that sufficient control samples are retained of the exact formulation being tested for direct comparison with the exposed coupons as they are removed.

For the sake of clarity, Figure 1 data also are shown in two additional graphs (Figures 3 and 4). There are two sets of curves plotted in Figures 3 and 4 for each environmental condition of this polyester resin. The accumulative PWC curve, as the name defines, shows the actual percentage weight change of the sample at a particular time as compared to its original weight. Greater accuracy is of course obtained wherever conditions permit these figures to be based upon multiple coupon averages. Examine first the accumulative line on Figure 3 which indicates the performance of the polyester resin exposed to butyl benzyl phthalate at 75-80 C for a period of 623 hours. You will note there is a rapid initial loss in weight of—0.14 percent after the first 50 hours of exposure. This loss in weight continues although at a much slower rate, until a maximum of —0.21 percent is reached after about 190 hours. After this period there is a gradual slight gain in weight, ending up at a total weight loss of about —0.17 percent on completion of the run of 623 hours. The most important points about this curve to be considered are: (1) the extent of its deviation from the no percentage weight change (0.0) base line, and (2) its slope. These are employed in predicting the estimated annual PWC for each specific resin. The slope of the accumulated PWC curve is determined for the last 400 hours of exposure. Extrapolation of the accumulative PWC curve at this

TABLE 2—Glass Fiber Reinforced Polyester Resins—Percentage Weight Change vs Flexural Strengths

Environment	PWC Total Run (623 Hrs.)	Slope of Accumulative PWC Curve (Last 400 Hrs.)	Predominating Trend Slope of Differential PWC Curve (Last 200 Hrs.)	Indicated Annual PWC (Extrapolation Based Upon Slope of Accumulative PWC Curve)	Flexural Strength Completion of Run (PSI)	Rating
1. Butyl Benzyl Phthalate	—0.17%	+.00010	0.00000	+0.70%	19,400	G
2. Di Butyl Phthalate	—0.18%	+.00005	—.00025	+0.26%	19,500	E
3. Di Ethyl Phthalate	+0.02%	+.00025	—.00020	+2.21%	12,900	P
4. Methyl Phthalyl Ethyl Glycollate	—0.07%	+.00012	—.00008	+0.98%	16,400	F
5. Butyl Phthalyl Butyl Glycollate	—0.16%	+.00008	0.00000	+0.54%	18,800	G
6. Isopropyl 2, 4-D Ester	+0.22%	+.00045	—.00025	+4.16%	13,400	P
Control					19,300	

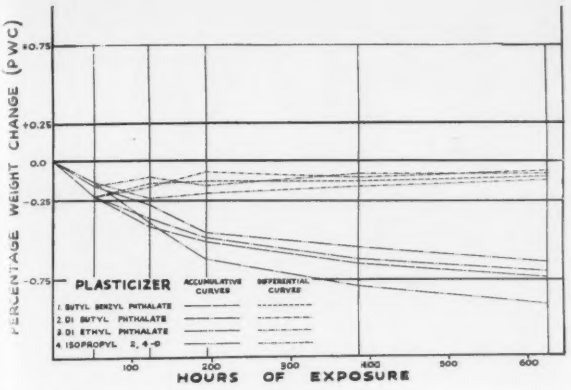


Figure 5—Performance of glass fiber reinforced epoxy resin in various plasticizers and esters in the range 75-80 C. Four plasticizers used.

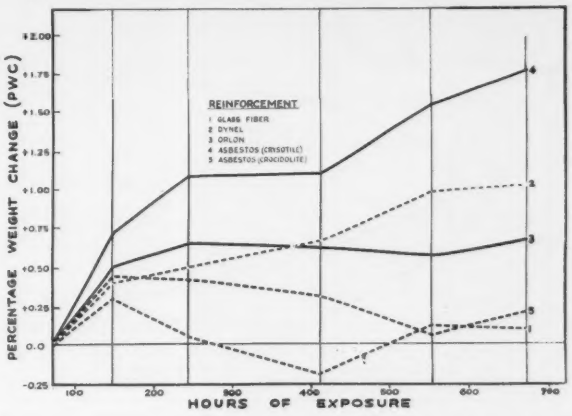


Figure 6—Performance of five different fiber reinforced epoxy resins in plant grade HCl.

rate of change from this point (400 hours prior to completion of run) for 8,760 hours gives the estimated annual PWC which serves as a basis for rating the performance of the resin system. Table 1 shows the arbitrary rating system devised which is based upon the observation of innumerable exposures of such plastics in various environments.

Plotted also in Figures 3 and 4 are a second set of curves referred to as the Differential PWC curves. These plot the individual weight changes between the successive weighings of each test coupon throughout the run. The differential PWC curve serves to indicate whether the rate of weight change is speeding up, slowing down, or remaining constant for any particular increment of time. The slope of the differential PWC curve for the last 200 hours of exposure shows the predominating trend in the rate of change in weight of the sample at the conclusion of the run. The information apparent from examination of the differential PWC curve and predominating trend serves to decide on the validity of the final rating of the material of construction. They tell whether additional testing is warranted before a decision can be reached for the use of the material under study.

It is interesting to note the variations in the differential PWC curves for the same polyester exposed in these several esters as shown in Figures 3 and 4. The curves for butyl benzyl phthalate and dibutyl phthalate follow each other closely and show very slight terminal losses in weight. That exposure in diethyl phthalate shows only a slight deviation of the polyester from the zero change base line, while the coupon in isopropyl 2, 4-D ester indicates an ever increasing gain in weight, a condition which makes the use of this polyester questionable in this latter service.

Table 2 details the numerical values for these curves, in addition to data covering the exposure of several other GFR polyester resins in similar environments. Examination of Table 2 discloses some interesting information regarding the performance of this particular polyester in these esters. First, it shows that a low percentage weight change for a particular exposure does not necessarily mean that the fiber reinforced-resin system is unaffected. Quite frequently the coupons experience an initial loss or gain in weight which is followed by a gradual return towards the original weight. Continued exposure may result in the complete failure of the material, whereas evaluation based upon a percentage weight change above would have indicated no appreciable change in the material and suggested its satisfactory application. This point may be readily discerned by referring to Figures 3 and 4 and Table 2. In the light of the percentage weight change (PWC) for the polyester coupons exposed within these several environments, it would appear at first glance that this particular GFR polyester resin was the least affected in the diethyl phthalate exposure. The 0.02 percent gain in weight after a 623 hour exposure certainly would appear quite insignificant. What must be considered, however, is its performance during the

TABLE 3—GFR* Epoxy Resins PWC vs Flexural Strengths**

Environment	PWC Total Run (623 Hrs.)	Slope of Accumulative PWC Curve (Last 400 Hrs.)	Predominating Trend Slope of Differential PWC Curve (Last 200 Hrs.)	Indicated Annual PWC (Extrapolation Based Upon Slope of Accumulative PWC Curve)	Flexural Strength Completion of Run (PSI)	Rating
1. Butyl Benzyl Phthalate	—0.74%	—.00045	+0.0002	—4.68%	36,600	P
2. Di Butyl Phthalate	—0.70%	—.00050	+0.0003	—5.08%	33,800	P
3. Di Ethyl Phthalate	—0.63%	—.00042	+0.00005	—4.33%	36,000	P
4. Methyl Phthalyl Ethyl Glycollate	—0.79%	—.00055	+0.0003	—5.61%	37,600	P
5. Butyl Phthalyl Butyl Glycollate	—0.89%	—.00058	+0.00035	—5.97%	36,100	P
6. Isopropyl 2, 4-D Ester	—0.92%	—.00072	+0.00012	—7.23%	36,800	P
Control					44,600	

* Glass Fiber Reinforced.
** Percentage Weight Change.

TABLE 4—Fiber Reinforced Epoxy Resins Exposed to 18° Bé Plant HCl PWC* vs Flexural Strengths

Epoxy-Reinforcing Fiber	PWC Total Run (672 Hrs.)	Slope of Accumulative PWC Curve (Last 400 Hrs.)	Predominating Trend Slope of Differential PWC Curve (Last 200 Hrs.)	Indicated Annual PWC (Extrapolation Based Upon Slope of Accumulative PWC Curve)	Flexural Strength Completion of Run (PSI)	Flexural Strength of Control (PSI)	Rating
1. Glass Fiber Roving Mat Volan "A" Finish	+0.104%	+0.0001	+.0008	+ 0.94%	25,900	49,800	F
2. Dynel Cloth	+1.019%	+0.0012	—.0005	+11.00%	11,100	16,900	P
3. Orlon Cloth	+0.665%	+0.00004	+.0004	+ 1.00%	17,300	19,500	F
4. Crysotile Asbestos Mat	+1.764%	+0.0016	+.0007	+14.30%	16,500	23,200	P
5. Crocidolite-Blue African Asbestos Mat	+0.212%	—0.0005	+.0009	— 0.01%	11,100	22,500	F

* Percentage Weight Change.

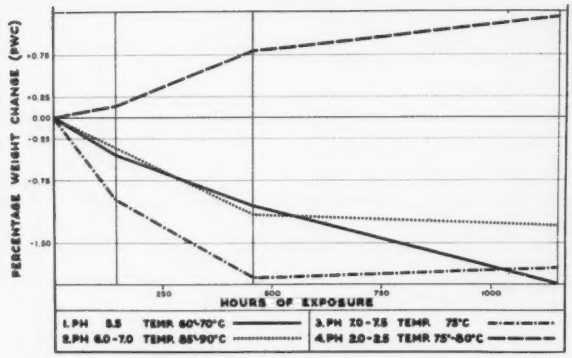


Figure 7—Performance of glass fiber reinforced polyester resin in salicylic acid—sulfuric acid—water.

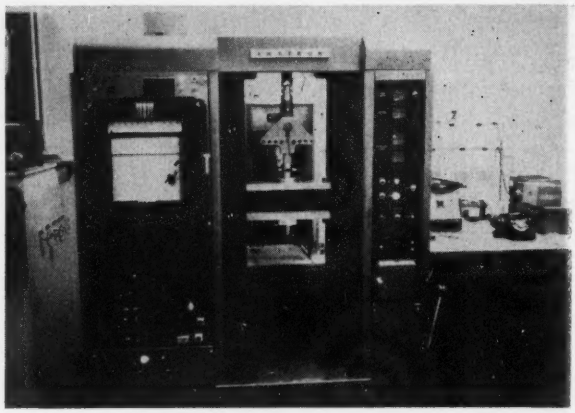


Figure 8——Instron tensile tester.

TABLE 5—Reinforced Epoxy Resins PWC* vs Flexural Strengths

Environment	Resin	Flexural Strength End of Run (PSI)	Flexural Strength Control (PSI)	PWC Total Run	PWC Extrapolated Annual Rate	Rating
Santicizer 160 80–85C 672 Hrs.	Epoxy 1	45,600	49,800	—0.036%	—0.53%	G
	Epoxy 2	15,400	16,900	+0.242%	+2.24%	P
	Epoxy 3	15,600	19,500	+0.008%	—0.23%	E
	Epoxy 4	17,500	23,200	—0.028%	—0.44%	G
	Epoxy 5	22,300	22,500	—0.114%	—0.61%	G
Santolube 333 85–90C 700 Hrs.	Epoxy 1	49,400	49,800	—0.086%	—1.75%	P
	Epoxy 2	16,000	16,900	—0.039%	—0.76%	G
	Epoxy 3	18,000	19,500	—0.101%	—1.10%	F
	Epoxy 4	23,000	23,200	—0.162%	—1.82%	P
	Epoxy 5	5,500	22,500	—0.280%	—1.95%	P

* Percentage Weight Change.

TABLE 6—Reinforced Polyester Resins PWC* vs Flexural Strengths

Environment	Resin	Flexural Strength End of Run (PSI)	Flexural Strength Control (PSI)	PWC Total Run	PWC Extrapolated Annual Rate	Rating
Formic Acid Storage Tank 85C–1200 Hrs.	Polyester	18,400	19,300	+1.20%	+1.20%	F
Acid Wash Water Settling Tank (70–80C–PH–2–3) 3768 Hrs.	Polyester 1	15,000	14,900	+0.08%	+0.24%	E
	Polyester 2	12,900	14,200	+0.12%	+0.28%	G
	Polyester 3	19,400	22,800	+0.22%	+0.47%	G
	Polyester 4	17,200	21,500	+0.33%	+0.85%	F

* Percentage Weight Change.

complete exposure. This varied from an initial loss in weight of 0.06 percent after 50 hours, through a later gain of 0.07 percent at the 192 hour mark and culminated in the net gain of 0.02 percent at the moment of its removal from the system. Extrapolation of the accumulative PWC curve indicates an annual PWC gain of approximately 2.2 percent which is beyond the limit of 0.75 percent considered acceptable. The loss in flexural strength to 12,900 PSI (67 percent) compared with a control coupon flexural strength of 19,300 PSI flexural strength would appear to substantiate the premise that the diethyl phthalate environment is not compatible with the polyester resin. On the other hand, the GFR polyester coupon exposed to dibutyl phthalate, which had a loss in weight of 0.18 percent during the exposure of 623 hours, has an estimated annual PWC gain of only 0.26 percent, and retained its original flexural strength. Although there are exceptions to any rule, it appears that a high degree of correlation exists between the rating (indicated annual PWC) of the GFR resin and the residual

TABLE 7—Glass Fiber Reinforced Polyester Resins Exposed in Salicylic Acid—H_2SO_4—Water

Environment	PWC* vs FLEXURAL STRENGTH CHANGES EXPOSURE PERIOD (HOURS) 144 Hr. Polyester	456 Hr. Polyester	1152 Hr. Polyester
1. pH = 5.5 Temp = 60–70 C			
PWC	— 0.44 Percent G	— 1.06 Percent F	+ 2.5 Percent P
Flexural Strength (PSI x 10–3)	19.1	15.9	16.7
Flexural Modulus (PSI x 10–5)	6.3	6.3	6.3
2. pH = 6.0–7.0 Temp = 85–90 C			
PWC	— 0.37 Percent G	— 1.17 Percent F	— 1.30 Percent F
Flexural Strength (PSI x 10–3)	18.1	16.7	10.3
Flexural Modulus (PSI x 10–5)	6.0	6.2	6.4
3. pH = 7.0–7.5 Temp—75 C			
PWC	— 0.77 Percent F	— 1.92 Percent P	— 1.80 Percent P
Flexural Strength (PSI x 10–3)	19.0	19.6	18.8
Flexural Modulus (PSI x 10–5)	6.4	5.6	6.3
4. pH = 2.0–2.5 Temp 75–80 C			
PWC	+ 0.14 Percent E	+ 0.80 Percent F	+ 1.2 Percent F
Flexural Strength (PSI x 10–3)	18.6	17.9	16.5
Flexural Modulus (PSI x 10–5)	5.2	5.5	5.2
CONTROL:			
Flexural Strength (PSI x 10–3)	21.2		
Flexural Modulus (PSI x 10–5)	7.8		

* Percentage Weight Change.

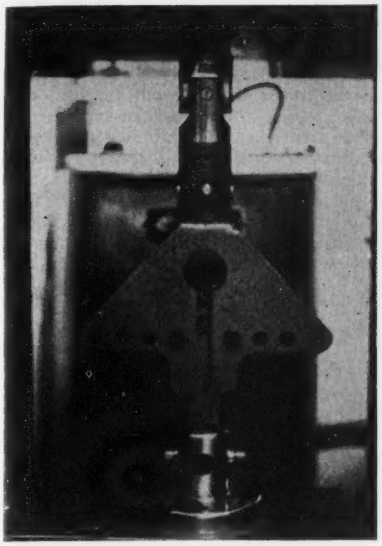


Figure 9—Close-up of flexural jig control center.

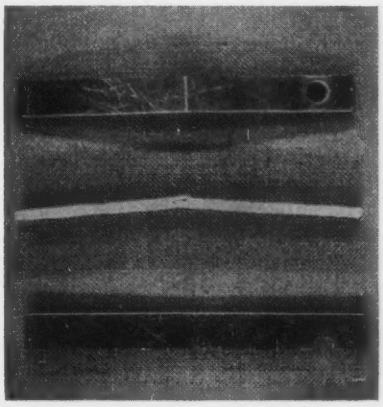


Figure 10—Test coupons after being subjected to flexural strength evaluations.

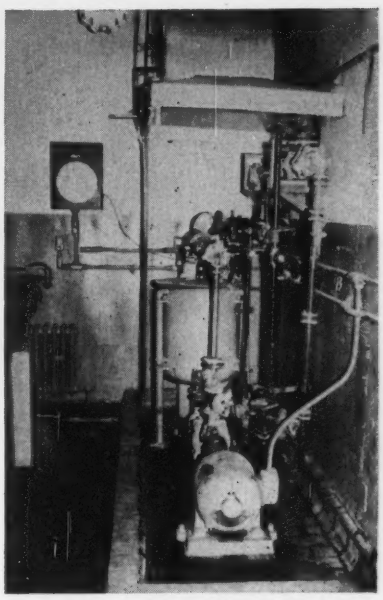


Figure 11—Erosion-corrosion testing equipment.

flexural strength. However, many more evaluations will need to be run before the existence of such correlation can be definitely established.

Figure 5 and Table 3 show the performance of a specific GFR epoxy resin when exposed to the same plasticizers and esters as was experienced by the polyester resin detailed in Figure 1 and Table 2. In no instance did the epoxy resin appear to fare as well as the polyester resin. The indicated high annual PWC for the epoxy resin in each exposure results in only poor (p) ratings. The flexural strengths were down appreciably (75-84 percent) from that of their original value. This particular GFR epoxy resin would not be acceptable in these environments. It should be considered that other GFR epoxy resins might perform more satisfactorily and be suitable in this service.

The performance of a specific epoxy resin reinforced with five different fibers and exposed in plant grade hydrochloric acid is shown in Figure 6 and detailed in Table 4. The loss in flexural strength as compared with the actual PWC is the most significant information disclosed here. This high loss (50 percent) in flexural strength makes the application of even the blue African asbestos mat reinforced epoxy resin questionable in this service. This, in spite of an extremely low indicated annual PWC of —0.01 percent. In this instance, if the project could stand the additional time for further evaluations, the three fiber reinforced epoxies rated fair (F) would be re-exposed for an additional 600 hour period. This would tell whether there are more optimistic changes in the accumulative PWC curves.

Table 5 shows the performance of these same five differently reinforced fiber epoxy resin systems exposed in Santicizer 160, and Santolube 333. In these environments there was very high retention of flexural strength (92-99 percent) for seven of the exposures, fairly good retention (75-80 percent) of the flexural strengths for two exposures, and one which fell to only 24 percent of its original flexural strength. Correlation between the residual flexural strength and the extrapolated annual PWC rate in several cases is not too good. There are a number of exposures in which the epoxy resin systems exposed in Santicizer flexural strengths were essentially unchanged. This may be an indication that no serious attack is occurring to these epoxy resins and that further exposure would result in a better annual PWC rating.

Table 6 shows some results of exposures of GFR polyesters in several field evaluations. The polyester suspended in the formic acid storage tank had an initial loss in weight of 1.20 percent within 96 hours. There was additional darkening of the sample but no further change in weight for the balance of the 1,200 hours. It retained 95 percent of its original flexural strength at the completion of the test run. This is an instance where a short term exposure might have indicated its inacceptability. A polyester tank has been used successfully in this service for over two years.

The GFR polyesters exposed to acid wash waters within a settling tank for a period of 3,768 hours show a fairly high degree of correlation between the extrap-

TABLE 8—Reinforced Resins Exposed in 28 Percent Hydrochloric Acid Storage Tank

Resins System	Hours	Percentage Weight Change	FLEXURAL STRENGTH (PSI x 10^{-3}) Control	FLEXURAL STRENGTH (PSI x 10^{-3}) Test Coupon	FLEXURAL MODULUS (PSI x 10^{-5}) Control	FLEXURAL MODULUS (PSI x 10^{-5}) Test Coupon
GFR Furan	528	—0.16% E		16.3		6.6
	4200	—5.60% P	18.1	6.2	9.9	2.2
GFR Polyester—A (Chemical Resistant)	528	+1.1 % F		25.5		7.8
	4200	+0.47% G	21.2	17.3	7.8	7.0
GFR Polyester—B (Fire Retardant—Chlorinated Co-Polymer)	528	+0.42% G		22.1		8.5
	4200	—0.71% G	19.2	16.9	8.5	7.7
GFR Polyester—C (Fire Retardant—Inorganic Filler)	528	+0.55% G		22.9		8.0
	4200	—0.25% G	20.4	23.5	8.8	9.0
GFR Polyester—D (General Purpose)	528	+0.24% E		26.5		10.0
	4200	—0.88% F	23.3	17.4	11.8	7.7
Acrylic Fiber Reinforced Polyester—E	528	+0.24% E		5.5		3.2
	4200	—0.88% F	7.0	6.9	3.7	2.7
GFR Epoxy	528	+1.8 % P		20.2		7.0
	4200	+3.8 % P	19.4	16.4	7.7	5.2
PVC	528	+0.07% E		15.1		4.1
	4200	+0.07% E	13.5		4.3	

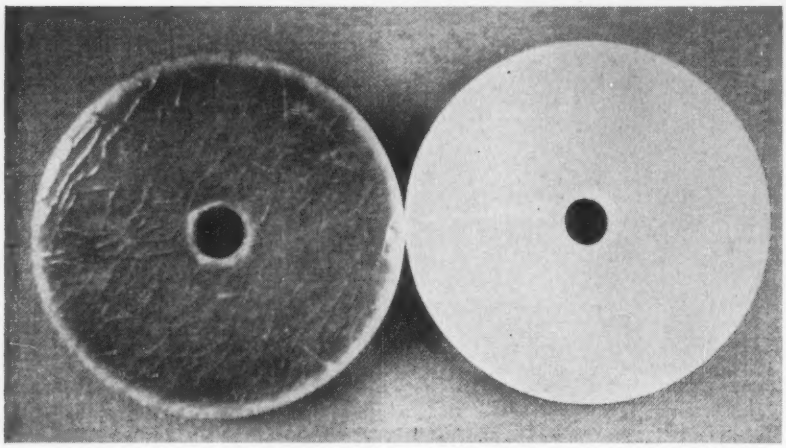


Figure 12—GFR polyester disc subjected to organic acid slurry (left). At right is unexposed control.

olated annual PWC rate and their residual flexual strengths.

Figure 7 and Table 7 show the performance of a glass fiber reinforced polyester resin exposed in a mixture of salicylic acid-sulfuric acid-water at various pH levels. The continuing divergence of the percentage weight change curves from the zero weight change line, as well as the ratings of either fair (F) or poor (P), indicate the inacceptability of this particular GFR polyester resin in these environments. In each instance there was a significant loss in flexural strength for each coupon substantiating the PWC ratings.

Table 8 covers the results of a series of field tests on various plastic materials of construction exposed in a 28 percent hydrochloric acid storage tank for a period of 4200 hours. With the exception of a few minor incongruities, a fairly high degree of correlation exists between the PWC and flexural strength change for most of the materials evaluated. The excellent resistance of a control coupon of polyvinyl chloride is apparent.

Table 9 compiles the experiences of various reinforced resins exposed for 3700 hours in a 50 percent maleic acid-water storage tank at 60-70 C. Once again a close correlation appears to exist between the PWC and flexural strength change for most of the exposures.

Tables 10 and 11 show the results of exposing various GFR resins for 2200 hours in phthalate esters wash water. It is significant that the chemical resistant GFR polyester resin is the only material tested which was acceptable in both of these environments. All of the materials show a high degree of correlation between the percentage weight and flexural strength changes. It is interesting to know that the GFR Polyester-A resin exposed in the butyl benzyl phthalate wash waters for 2200 hours showing a PWC rate of +0.5 percent with only a slight change in flexural strength was a continuation of that referred to in Table 2 with an indicated annual PWC of +0.70 percent after 623 hours of exposure.

Although the exposed coupons could be subjected to numerous physical tests in the evaluation of the performance of fiber reinforced resins, it was decided to employ flexural strength evaluations since this appeared to be the most indicative fundamental physical behavior of these materials. The Instron tensile tester illustrated in Figure 8 is the instrument which is used in these determinations. This unit utilizes electronic principles for both the weighing of the forces on the sample and for controlling its extension while still preventing the characteristics of the machine from obscuring the accuracy of the results. Its highly sensitive electronic weighing system employs bonded-wire strain gages for detecting and recording the load applied to the sample under test. A close-up of the nerve center flexural jig is illustrated in Figure 9. Figure 10 shows a number of test coupons which have already been subjected to the flexural strength evaluations, the points of failure being quite evident.

As the occasion demands, other special physical tests are made. The question of abrasion resistance is generally answered in either of two ways. The first way is by application of the erosion-corrosion equipment, illustrated in Figure 11, which equipment is the property of the Research and Engineering Department Corrosion Laboratory. This set-up is a modification of that unit designed by and used at Ohio State Metallurgical and Corrosion Laboratories by Dr. Mars Fontana. This unit employs a test disc spinning at 1750 RPM against which is impinged the slurry or liquid being evaluated. The spent slurry returns to the 30 gallon catch tank where it is again picked up and re-circulated against the spinning disc. Figure 12 compares a 4 inch diameter x ½ inch thick GFR polyester disc subjected to an organic acid

TABLE 9—Reinforced Resins Exposed in Maleic Acid Storage Tank*

Resins System	Percentage Weight Change	FLEXURAL STRENGTH (PSI x 10^{-3})		FLEXURAL MODULUS (PSI x 10^{-5})	
		Control	Test Coupon	Control	Test Coupon
GFR Furan	+4.5 P	18.1	15.9	9.9	7.1
GFR Polyester—A (Chemical Resistant)	—1.08 F	21.2	19.6	7.8	7.1
GFR Polyester—B (Fire Resistant Chlorinated Co-Polymer)	+0.57 G	19.2	19.8	8.5	8.7
GFR Polyester—C (Fire Resistant-Inorganic Filler)	+0.65 G	20.4	21.7	8.8	6.6
GFR Polyester—D (General Purpose)	+0.63 G	23.3	30.3	11.8	11.5
Acrylic Fiber Reinforced Polyester—E	—0.16 E	7.0	4.1	3.7	5.1

* Environmental Conditions: 50 Percent Maleic Acid—Water Temperature 60–70 C, Mild Agitation—3700 Hour Exposure Period.

TABLE 10—Fiber Reinforced Resins Exposed in Butyl Benzyl Phthalate Wash Waters (Alternate Acidic-Alkaline Conditions 2200 Hours)

Resins System	Percentage Weight Change	FLEXURAL STRENGTH (PSI x 10^{-3})		FLEXURAL MODULUS (PSI x 10^{-5})	
		Control	Test Coupon	Control	Test Coupon
GFR Furan	— 1.5% P	18.1	15.0	9.9	4.6
GFR Polyester—A (Chemical Resistant)	+ 0.5% G	21.2	19.0	7.8	7.3
GFR Polyester—B (Fire Retardant—Chlorinated Co-Polymer)	+10.6% P	19.2	7.7	8.5	1.8
GFR Polyester—C (Fire Retardant—Inorganic Filler)	+10.8% P	20.4	6.2	8.8	1.3
GFR Polyester—D (General Purpose)	+ 2.6% P	23.3	13.2	11.8	5.4
Acrylic Fiber Reinforced Polyester—E	+ 1.1% F	7.0	6.8	3.7	4.0
GFR Epoxy	+ 2.7% P	19.4	15.9	7.7	6.4

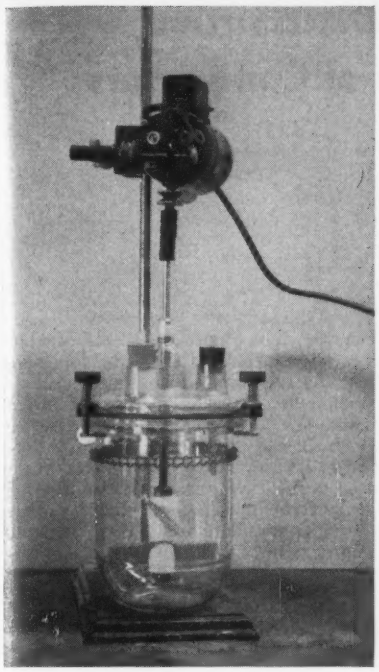


Figure 13—Laboratory erosion-corrosion test unit.

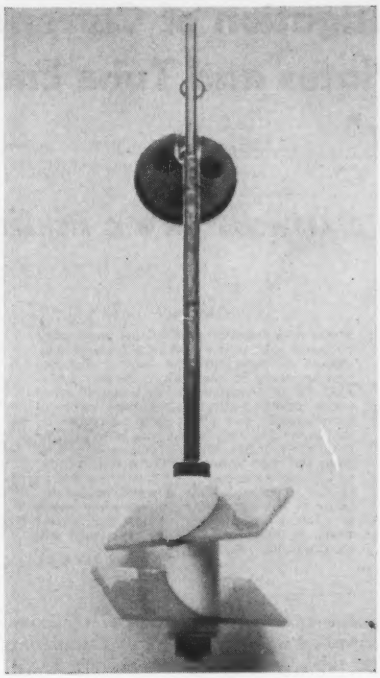


Figure 14—Close-up of agitator for test unit pictured in Figure 13.

TABLE 11—Fiber Reinforced Resins Exposed in Phthalate Esters Wash Waters (Alternate Acidic-Alkaline Conditions—2200 Hours Exposure)

Resins System	PWC	FLEXURAL STRENGTH (PSI x 10^{-3})		FLEXURAL MODULUS (PSI x 10^{-5})	
		Control	Test Coupon	Control	Test Coupon
GFR Furan	— 0.33 G	18.1	17.8	9.9	8.7
GFR Polyester—A (Chemical Resistant)	+ 0.74 G	21.2	23.0	7.8	7.9
GFR Polyester—B (Fire Retardant Chlorinated Co-Polymer)	+12.3 P	19.2	7.7	8.5	1.7
GFR Polyester—C (Fire Retardant Inorganic Filler)	+14.2 P	20.4	7.1	8.8	1.1
GFR Polyester—D (General Purpose)	+ 4.2 P	23.3	24.3	11.8	7.4
Acrylic Fiber Reinforced Polyester—E	+ 1.1 F	7.0	7.6	3.7	4.2
GFR Epoxy	+ 3.9 P	19.4	17.3	7.7	6.5

slurry (shown on the left) with that of an unexposed control. The high degree of crazing which occurred to the exposed sample is quite noticeable. The second method of checking abrasion resistance is illustrated in Figure 13 which shows the construction of a small laboratory erosion-corrosion unit in which the test coupons serve as both agitator blades and baffles. Figure 14 is a close-up of the agitator showing the polyester blades and Teflon spacers. The spacers between the test coupons may be modified to permit any desired agitation by changing the pitch of the coupons on the shaft as required. The slurry in question is evaluated for abrasiveness against slurries of known properties, as well as with the plastic materials of construction being studied currently.

Conclusions

Determination of the accumulative and differential percentage weight change (PWC) curves by periodic removal and measurement of test GFR resin coupons exposed within a questionable environment results in a valuable tool for the evaluation of these reinforced plastics as materials of construction. Losses in flexural strength of a specific fiber reinforced resin system appear to show a high degree of correlation with the indicated annual PWC, as extrapolated from the accumulative percentage weight change curve. The rating system serves as a basis for expressing the performance of fiber reinforced resins in corrosive environments which can be easily communicated.

Further, long range performance studies are in progress on the evaluation of this rating system employing field testing of both proprietary resins and test coupons, and specially formulated test samples prepared in the Organic Research Laboratories of the Monsanto Chemical Company. The results of these tests will help to establish the value of the accelerated rating system for GFR resins.

Acknowledgments

The authors wish to acknowledge the helpful assistance of Douglas Reinhard, University of Michigan and Joe R. Jeter, J. F. Queeny Plant Corrosion Section, in this study.

Any discussion of this article not published above will appear in June, 1961 issue.

Laboratory Investigation of Current Distribution On Brass Tube Plates and Tube Ends of Condensers Using Sea Water★

By P. G. ATTWOOD* and W. G. RICHARDS*

Abstract

Static and dynamic experiments were made on brass tube plates and tube ends of condensers to determine the current distribution on them in sea water. Factors evaluated in this connection include effect of water velocity, effect of coatings, effect of temperature, and effect of composition of the anode and tube materials. It was found that most of the galvanic current flowing from ferrous components (or a steel anode) to a non-ferrous condenser tube sheet flowed to the tubes with only a small proportion going to the tube plate. A zinc alloy anode provided a much higher current than a steel anode to both an Admiralty brass tube and an aluminum brass tube.

7.4.2, 3.6.6, 4.6.11, 5.2.1

Introduction

CORROSION OF condensers and coolers in oil refineries is severe when sea water is used as the coolant. The sea water functions as the electrolyte in a galvanic cell in which the ferrous parts in the channel or floating head ends of a condenser act as anode and the non-ferrous parts as cathode. Thus, if no protection is provided, the ferrous parts suffer severe galvanic corrosion.

An effective method of mitigating this corrosion is to include sacrificial anodes in the system. Because of space limitations, such anodes must necessarily be small. The current drain from these anodes must also be small since it is neither economical nor convenient to replace them at short intervals. Therefore, to increase anode life, a suitable coating can be applied to the ferrous parts so that the anodes will be required to protect only at breaks in the coating.

It follows that some current will flow to the non-ferrous components, and thus coating these parts will also increase anode life. With reference to this, the question arises as to whether only the tube plate should be coated, or whether the coating should also be applied to the tube ends and to part of the tube bore. The static experiments described in this paper were conducted in an attempt to answer this question and to determine the effect of protruding tubes. The dynamic experiments cover the effects of water velocity, coatings, tube material and anode material on current distribution down the tube bore.

Experimental Work

Apparatus

A model of a condenser water box was constructed by supporting a rectangular polythene bowl, 12 inches x 9½ inches x 5½ inches, on a ¼-inch thick laminated plastic plate and mounting it on a framework, 3 feet above ground level. A 6-inch square 70/30 brass plate, containing seven 13/16-inch diameter holes with centers 15/16-inch apart in triangular array, was fixed to the bottom of the bowl. A neoprene gasket was fitted between the brass plate and the bottom of the bowl to prevent leaking.

For the static experiments, seven 3-inch lengths of ¾-inch OD Admiralty brass condenser tubing were fitted into the holes in the brass plate, with polythene bushes around the top ends of the tubes providing water-tight seals and insulating the tubes from the plate (Figure 1). A 4-inch diameter hole was cut in the neoprene gasket, the bottom of the bowl and the laminated plastic plate to allow the tubes to project below the bowl. The lower ends of the tubes were provided with rubber bungs so that the bowl could be filled with water.

In the dynamic experiments the six outer holes in the brass plate were plugged with rubber bungs and a 14-inch length of Admiralty brass tubing was fitted into the center hole.

The edges of the brass plate were coated with an epoxy resin so that only the top surface of the plate, the tube bores and the top edges of the tubes were in contact with the water. A steel anode, in the form of a ¼-inch thick steel plate, 6 inches x 4 inches, coated on the edges and one side with epoxy resin, was held horizontally in the surface of the water 4¼ inches above the brass plate.

Currents were measured in the static experiments by completing the circuit externally through an ammeter, and in the dynamic experiments by recording the potential drop across a standard 2 ohm resistance with a portable potentiometer.

Static Experiments

The first approach to the problem was the measurement of potentials, relative to a miniature silver/silver chloride half-cell, at various points in the sea water. This was done in the hope that a complete current distribution in the system could be obtained. This was not possible, however, because of large fluctuations of the total current flowing in the system. A steadier current was obtained using tap water, but even so, potential surveys could be made only at points close to the brass surfaces. These measurements showed that there was a lower vertical component of current to the brass plate in the region of the tubes than to the outer area of plate, and that there was a component of current perpendicular to the inner surface of the tube for more than 2½ inches down the tube bore.

Some direct current measurements were made with tap water using an ammeter which showed that although only 10 percent of the surface area of the brass plate was occupied by tube ends, the ratio of the current flowing to the tubes to that flowing to the plate was 0.75. This result is in agreement with the potential measurements.

There was an increase of approximately 50 percent in the current to a tube when the tube protruded ¼ inch above the surface of the brass plate. This additional current flowed to the outer surface of the tube, since placing a polythene collar around this surface reduced the current to the value obtained when the tube was flush with the plate.

Thus, this work shows that most of the current flowing to the tube sheet flows to the tubes and only a small proportion to the tube plate. Furthermore, current flows down the tube bore and protruding tubes function as "current collectors."

Dynamic Experiments

The water box model was modified so that sea water could be circulated, by means of a centrifugal pump, from a container at ground level to the bowl and back again under gravity via the 14 inch length of Admiralty brass condenser tubing. A flow diagram of the system is shown in Figure 2. Current distributions down the tube bore were obtained by measuring the equilibrium current flowing to known lengths of bore. The length of the bore exposed to the flowing sea water was varied by sliding a 16-inch length of glass tubing inside the brass tube. A ⅜-inch long PVC bush was located around the top end of the glass tube to effect a water-tight seal between the glass and condenser tubes. The arrangement of the glass tube inside the condenser tube is shown in Figure 3.

Effect of Water Velocity. With the water level in the bowl 2 feet 9 inches above the level in the lower vessel, the water velocity down the condenser tube was 4 ft/sec. A water meter was included in the circuit so that a measure of the velocity could be obtained. The water flow was controlled by applying a variable constriction to the flexible tube connecting the glass tubing to the water meter. In this way equilibrium currents to 13 inches of the tube were obtained at a series of water velocities between 0 and

★ Submitted for publication March 28, 1960.

* The British Petroleum Company Limited, Petroleum Division, Research Centre, Chertsey Road, Sunbury-on-Thames, Middlesex, England.

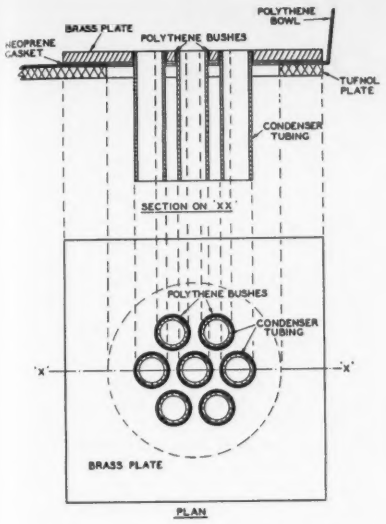


Figure 1—Brass plate and tube arrangement.

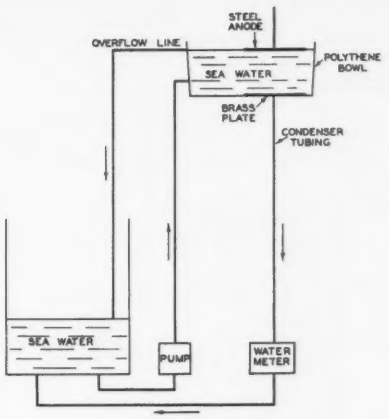


Figure 2—Flow diagram.

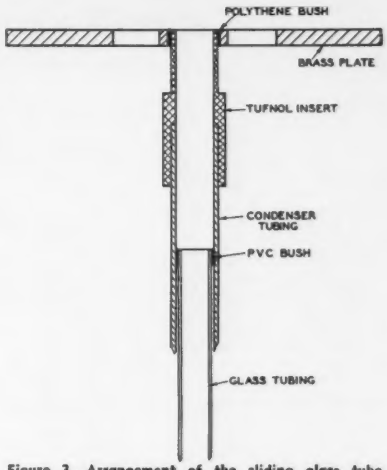


Figure 3—Arrangement of the sliding glass tube inside a condenser tube fitted with a laminated plastic insert.

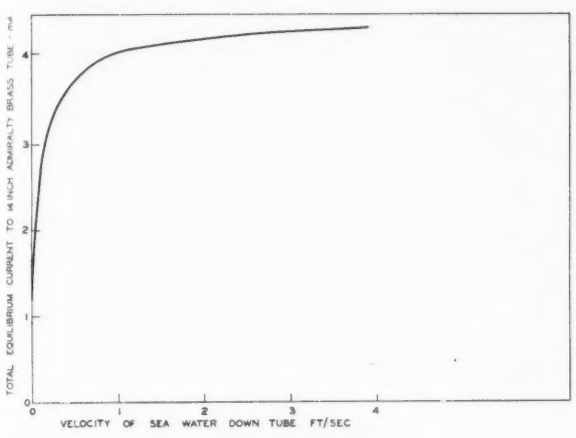


Figure 4—Effect of water velocity on total current.

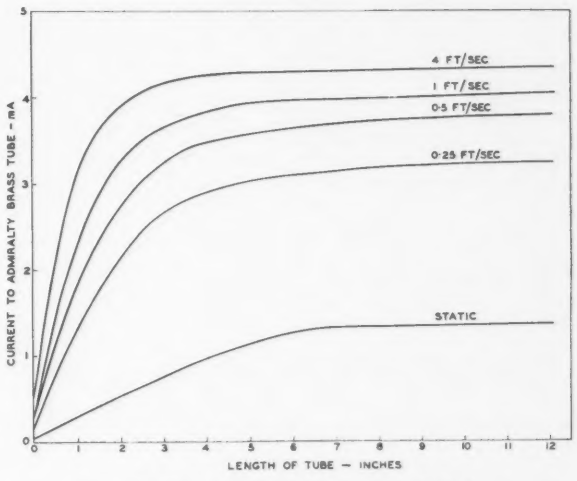


Figure 5—Effect of water velocity on current distribution.

4 ft/sec (Figure 4). There was only a slight decrease in current, from 4.35 mA to 4.06 mA, as the water velocity decreased to 1 ft/sec; below this velocity the current decreased more rapidly to 3.73 mA at 0.5 ft/sec and 1.2 mA under static conditions. It would appear from these results that at water velocities below 1 ft/sec, polarization effects become pronounced.

Current distributions at different water velocities are drawn in Figure 5 which shows that most of the current flows to the first 3 inches of tube. It is evident also that the polarizing layer causes the reduced current, obtained at velocities below 1 ft/sec, to spread further down the tube. The total equilibrium current to the tube was unsteady. In order to be able to compare distributions, each current was multiplied by the ratio of the appropriate total current, obtained from Figure 4, to the total current obtained when the distribution was determined.

Some experiments were conducted with the water flowing up the tube at 4 ft/sec. A direct comparison was not possible, but the results suggested that the reversed water flow had little effect on the total equilibrium current. The flow of current down the tube was slightly restricted in these experiments.

Effect of Coatings. A number of current distributions down the tube were obtained, at a water velocity of 4 ft/sec, with the top edge of the tube and various lengths of the bore coated with an epoxy resin. A cold-curing resin was used to avoid any possible effects on the results from heating the tube material. Consequently, due to the long curing time of the resin, these distributions took several days to complete and, because of total current variations, could not be directly compared.

In order to obtain a basis for comparison, a number of laminated plastic inserts of different lengths were made which were fitted successively to the brass tube to give, in effect, different lengths of perfect tube coating (Figure 3). A set of total equilibrium currents was obtained by interchanging the inserts. The distributions were then "corrected" by multiplying them by the ratio of the appropriate total current using a laminated plastic insert to the total current of the distribution. The "corrected" distributions are plotted in Figure 6. They show that although a short length of coating reduces the total current to a tube, there is a higher current density at the uncoated surface of the tube. This effect was evident in all the experiments using coating or laminated plastic inserts, including those in which a water velocity of 0.5 ft/sec was employed, and those in which the water was made to flow in the opposite direction.

Effect of Temperature. Increasing the temperature of the sea water from room temperature to 45 C almost doubled the current which flowed from a steel anode

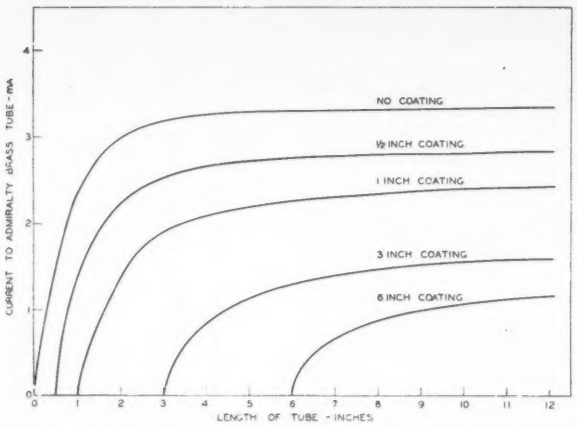


Figure 6—Effect of coating on current distribution with water velocity at 4 ft/sec.

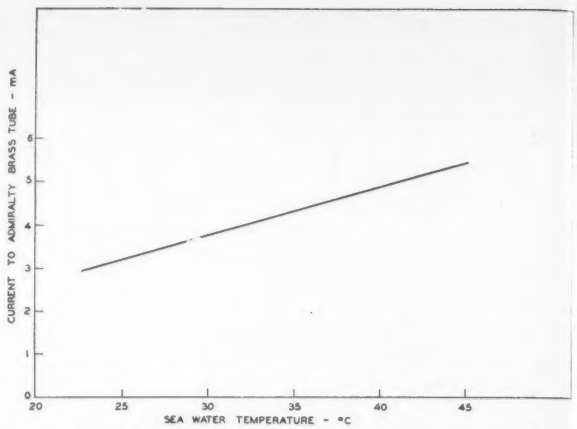


Figure 7—Temperature effect on total current with water velocity at 4 ft./sec

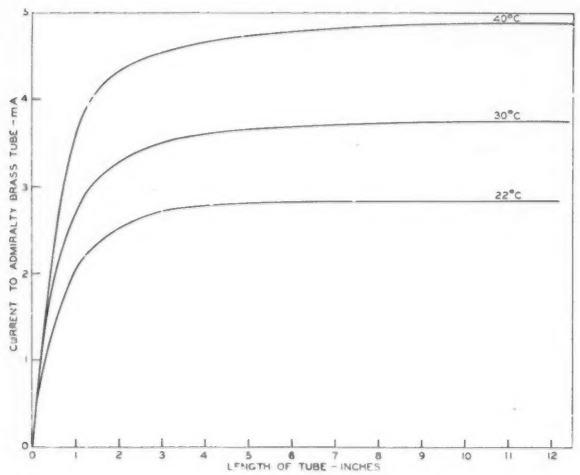


Figure 8—Temperature effect on current distribution with water velocity at 4 ft/sec.

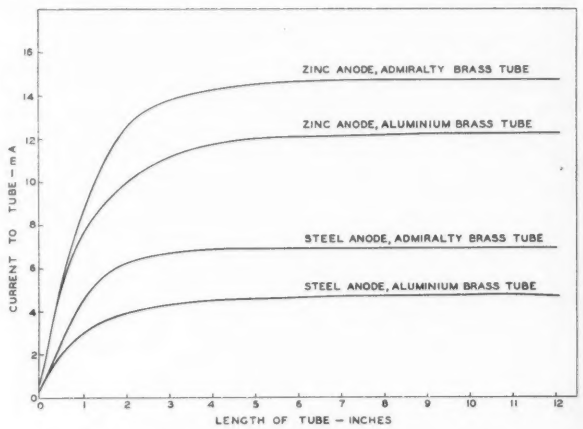

CURRENT TO TUBE - mA
ZINC ANODE, ADMIRALTY BRASS TUBE
ZINC ANODE, ALUMINIUM BRASS TUBE
STEEL ANODE, ADMIRALTY BRASS TUBE
STEEL ANODE, ALUMINIUM BRASS TUBE
LENGTH OF TUBE – INCHES

Figure 9—Current distributions on tubes with water velocity at 4 ft/sec.

to an Admiralty brass tube (Figure 7). Distributions down the tube were measured at three temperatures in this range, but the results given in Figure 8 show that the spread of current down the tube is not affected by a change in temperature.

Comparison of Anode and Tube Materials. In the experiments described so far, three different pieces of Admiralty brass tubing were used. Current distributions down two of these tubes were compared with and without coatings and it was found that, in each case, there was a greater spread of current down one tube than the other. For example, with 3 inches of bore coated, 81 percent of the total current to the first tube flowed to the first 6 inches of the bore, while 94 percent of the total current flowed to the first 6 inches of the bore of the second tube. This fact suggests that the current distribution, as well as the total current, is affected by the condition of the internal surface of the tube.

Current distributions were also obtained with an Admiralty brass tube and an aluminum brass tube, using both a steel anode and a zinc alloy anode at a water velocity of 4 ft/sec. The results, given in Figure 9, show that a much higher current is collected by both tubes from the zinc alloy anode than from the steel anode. Furthermore, the aluminum brass tube collects less current from both anodes than does the Admiralty brass tube. The current to the aluminum brass tube spreads slightly further down the bore than the current to the Admiralty brass tube.

Conclusions

1. Most of the galvanic current flowing from ferrous components, or a steel anode, to a non-ferrous condenser tube sheet flows to the tubes, and only a small proportion to the tube plate. Furthermore, protruding tube ends appear to function as "current collectors."

2. The total current to the brass tubes increases with increasing water velocity in the range 0-4 ft/sec. About 90 percent of this current flows to the tube ends and the first 3 inches of tube bore.

3. Increasing the water temperature from room temperature to 45 C almost doubles the total current to a tube.

4. Coating the tube end and the first few inches of bore with an epoxy resin reduces the total current to the tube, but the current density on the bore beyond the coating is increased.

5. A zinc alloy anode provides a much higher current than a steel anode to both an Admiralty brass tube and an aluminum brass tube.

6. A higher current flows to an Admiralty brass tube than to one of aluminum brass from both a steel and a zinc anode, although the current flows slightly further down the bore of the aluminum brass tube in each case.

Acknowledgment

The authors wish to thank the Chairman and Directors of the British Petroleum Company for permission to publish this paper.

Effect of Various Curing Agents On the Chemical Stability of Epoxy Resins*

By RONALD L. DeHOFF

Abstract

The epoxy resins most widely used in corrosion prevention are liquids of low molecular weight which can be converted to hard, tough, chemically resistant polymers by the use of various curing agents. Unlike other thermosetting resins such as polyesters, the curing agents may produce chemical linkages in the final polymers that differ from those present in the uncured form. Hence, the properties of cured epoxy resins are likely dependent upon, and may even reflect the properties of the curing agent used.

Some seven different epoxy resin systems were exposed to various chemical environments and evaluatd for changes in dimensional stability and flexural strengths over a six month period. From the data presented herein, only limited conclusions may be drawn. Heat cured systems fare better than room temperature cured systems in every case. Anhydride cured epoxy resins show greater resistance to outdoor weathering than amine cured systems. 5.4.5, 6.6.8

Introduction

THE EPOXY resins were first produced in commercial equipment less than ten years ago. In this period although product quality has increased and prices have decreased, the basic resin structure remains unchanged. The raw materials, bisphenol-A and epichlorohydrin are still the precursors and the groups active in resinification are the terminal epoxides as well as the secondary hydroxyles. The process of preparation is well known and the end products range from honeylike liquids to tough, horny, solids as the molecular weight increases from 340 upwards. The basic structure of epoxy resins is shown in Figure 1.

As one can understand, all of these resins contain a wide spectrum of molecular species. An approximation of the value of "n" for typical commercial epoxy resins is given in Table 1.

Initial work with epoxy resins produced some excellent coatings based upon solvent solutions of the solid grade resins. However, as the years progressed a need for a 100 percent solids coating system became evident. This is an area in which it appears that a formulation based upon the liquid grade resins such as Epon 828 or Epon 815 may be most useful. It is the former material which will be discussed in this paper. A study was undertaken therefore to investigate the properties of the cured liquid epoxy resins in corrosive environments. In addition to immersion in various chemical solutions, specimens were exposed to outdoor weathering to determine the effect of ultraviolet absorption on polymer properties.

Three different cure mechanisms were investigated with curing agent concentrations and cure cycles chosen to produce optimum polymer properties. Heat deflection point measurements (ASM Method D 648-56) were used as criteria for completeness of cure in this work.

Curing of Liquid Epoxy Resin

Epon 828 is essentially the diglycidyl ether of bisphenol-A. It differs from this in that it contains a small amount of polymeric material corresponding to an "n" value of about 0.10 as previously shown. This is, as a matter of fact, a fortuitous occurrence since the pure diglycidyl ether of bisphenol-A is actually a solid material, melting at about 45 C. It is the impurities present that transform it to a "supercooled" liquid.

As stated above, the chemical linkages of this epoxy resin other than carbon to carbon include two ether linkages and two terminal epoxide groups. Unlike other resins of the thermosetting type, curing may produce a plurality of linkages in the final polymer of a type not originally present in the monomer. There are three fundamental curing mechanisms that can be used to produce a highly crosslinked thermoset polymer. These include catalysis via tertiary amines or Lewis acids, curing with acids or anhydrides, and curing with amines. These are thought to proceed along the lines shown in Figure 2.

*Submitted for publication March 22, 1960. A paper presented at the 16th Annual Conference, National Association of Corrosion Engineers, Dallas, Texas, March 14-18, 1960.

About the Author

RONALD L. DeHOFF is presently Supervisor of Thermosetting Resins, Plastics and Resins Department at the Union Technical Service Laboratory of the Shell Chemical Company, Union, New Jersey. He is a member of the American Chemical Society, The Society of Plastic Industry, and the Society of Plastics Engineers. He graduated from the University of Alabama in 1938 with a BS degree in Chemical Engineering. After 10 years in resin development with the American Cyanamid Company, he joined Shell Chemical Company in 1951 and has since been engaged in technical service and development of epoxy resins and curing agents.

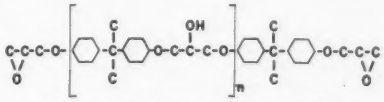


Figure 1—Basic structure of epoxy resins.

1. By Catalytic Polyether Formation

Two general mechanisms have been postulated for the formation of polyethers from epoxy-containing compounds. It is probable that, with commercial epoxy

TABLE 1—Typical Average Values of Repeating Unit "n" in Epoxy Resins

Epoxy	Value	State
Epon 828	n = 0.1	Liquid
Epon 834	n = 0.5	Liquid
Epon 836	n = 1.0	Semi-solid
Epon 1001	n = 2.0	Solid
Epon 1004	n = 6.0	Solid
Epon 1007	n = 14.0	Solid
Epon 1009	n = 24.0	Solid

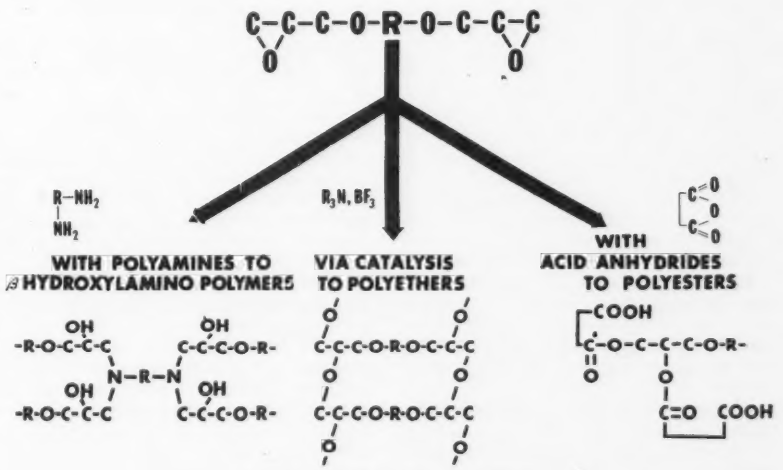


Figure 2—Polymerization of epoxy resins.

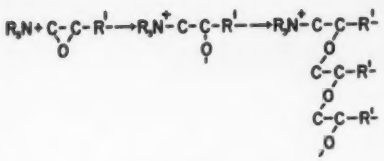


Figure 3—Curing mechanism occurring in presence of tertiary amines.

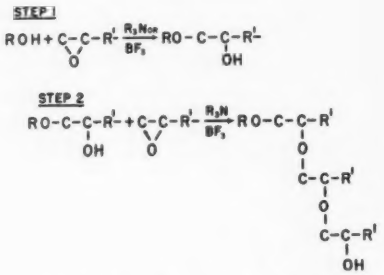


Figure 4—Opening of the epoxy ring under influence of catalyst.

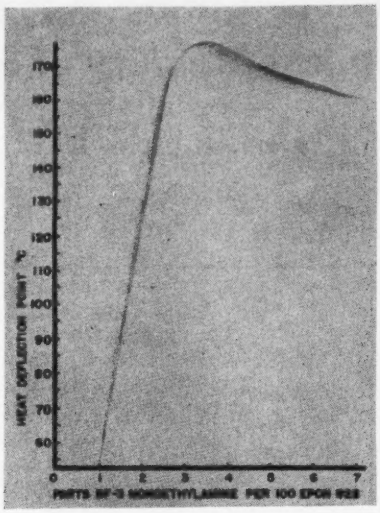


Figure 5—Dependence of curing on concentration of catalyst (parts BF-3 monoethylamine per 100 Epon 828).

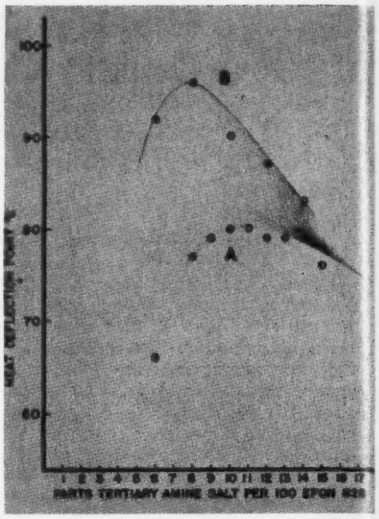


Figure 6—Effect of concentration on heat deflection point using a tertiary amine salt with an epoxy.

TABLE 2—Concentrations and Cure Conditions Used to Prepare Epoxy Resin Polymers (Epon 828) for Immersion Testing

Converting Agent	Symbol	PHR*	CURE CYCLE			
			Pre-Cure		Post-Cure	
			Time (hrs.)	Temp. (°F)	Time (hrs.)	Temp. (°F)
Boron Trifluoride Monoethylamine	BF_3 400	3	3	248	1	400
Phthalic Anhydride[1]	PA	75	2	248	24	300
Epon Curing Agent Z	Z	20	2	176	2	300
Diaminodiphenyl-sulfone[2]	DADS	20	2½	248	2	400
Chlorendic (HET) Anhydride	HET	110	3	300	16	356
Triethylenetetramine	TETA	14	21 days at 23C		...	...
m-phenylenediamine	CL	14	2	176	2	300

[1] Benzyldimethylamine at 0.5 phr used as an accelerator.
[2] Boron trifluoride monoethylamine at 1 phr used as an accelerator.
* Parts per hundred of resin.

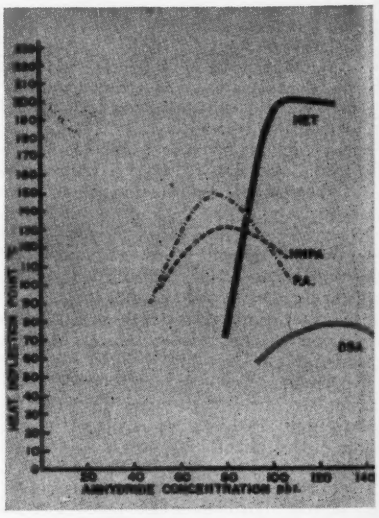


Figure 7—Dependence of heat deflection point on anhydride concentration.

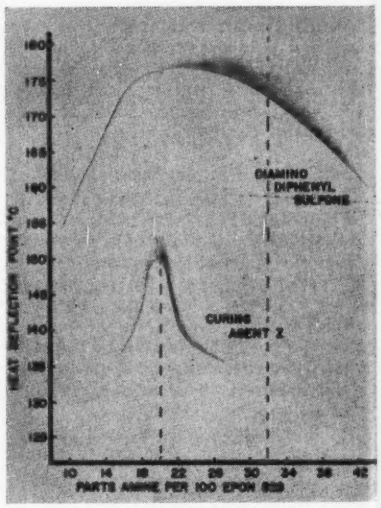


Figure 8—Curing of aromatic polyamine-epoxy resin systems.

resins under normal conditions of use, polyether formations occur simultaneously by both mechanisms and by other as yet unrecognized reactions; the predominance of one reaction over another is determined by the nature of the catalyst, the impurities, and the polymerization temperatures.

The first curing mechanism is most commonly represented as occurring in presence of tertiary amines and proceeds as shown in Figure 3.

In step 1, the tertiary amine opens an epoxy ring forming a quaternary base with unsatisfied electrons on the oxygen atom. In step 2, the negatively charged oxygen opens another epoxy ring, and in this fashion a long chain is built up.

In the case of a mono epoxy compound such as allyl glycidyl ether (where R′ contains no epoxy group) a linear, thermoplastic polymer results. Where R′ contains one or more epoxy groups, as it does with epoxy resins, it is possible to build up a three-dimensional polymer by cross-links between chains. Such polymers are thermoset and are infusible and insoluble.

The second postulated mechanism for polyether formation involves the opening of the epoxy ring by an alcohol or water molecule under the influence of the catalyst as shown in Figure 4. Presumably any hydroxyl groups originally present on the epoxy resin molecule would function in the manner shown in Figure 4.

Strong Lewis acids such as boron trifluoride or stannic chloride are very effective in promoting polyether polymerization. These systems are insensitive to the presence of small amounts of hydroxyl material; however, they are excellent promotors for the reaction of a hydroxyl group with an epoxy group. They obviously cause polyether formation by a mechanism different from that of tertiary amines and it is postulated that the initial reaction of the Lewis acid is formation of a relatively strong coordination complex between the electron-accepting atom of the Lewis acid (the boron in the case of BF_3) and the unshared electrons on the epoxy oxygen. This further strains the epoxy ring and tends to produce a more highly electropositive carbon which may then become involved in a reaction with either extraneous hydroxyl groups or other epoxy rings. It is characteristic of Lewis acid-catalyzed polyether formation that the reaction may involve either the alpha or the beta epoxy carbon while the amine-catalyzed reaction is almost exclusively with the alpha carbon. This lends support to the hypothesis that the Lewis acid attacks the oxygen of the epoxy ring

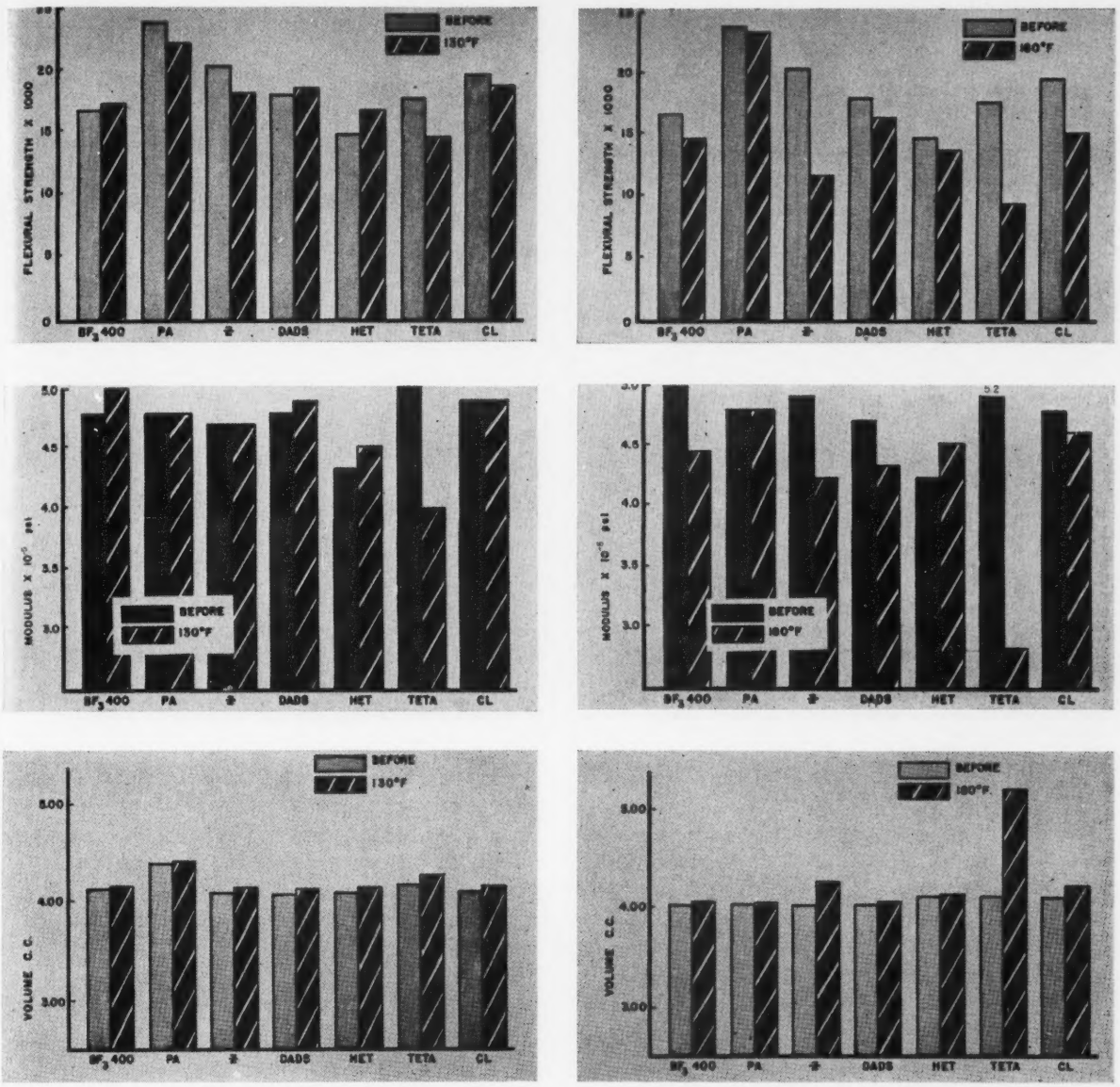


Figure 9—Effect of distilled water (left three graphs) and 25 percent sulfuric acid (right three graphs) on epoxy resin systems. Top two graphs show effect on flexural strength, center two graphs the effect on flexural modulus, and bottom two graphs the effect on dimensional stability.

TABLE 3—Concentrations and Cure Conditions Used to Prepare Epoxy Resin Polymers (Epon 828) for Outdoor Weathering Study

Converting Agent	Symbol	PHR*	CURE CYCLE			
			Pre-Cure		Post-Cure	
			Time (hrs.)	Temp. (°F)	Time (hrs.)	Temp. (°F)
Diethylenetriamine	DTA	10	24	RT	2	212
Triethylenetetramine	TETA	12	24	RT	2	212
m-phenylenediamine	CL	14	2	176	24	300
Epon Curing Agent Z	Z	20	2	176	24	300
Boron Trifluoride Monoethylamine	BF_3 400	3	4	248	24	300
Nadic Methyl Anhydride[2]	NMA	90	2	248	24	300
Diaminodiphenyl-sulfone[1]	DADS	20	2	248	24	300
Hexahydrophthalic Anhydride[2]	HHPA	80	2	248	24	300
Chlorendic (HET) Anhydride	HET	117	2	248	24	300
Dodecenylsuccinic Anhydride	DSA	134	2	248	24	300

[1] 1 phr of boron trifluoride monoethylamine as an accelerator.
[2] 1 phr of benzyldimethylamine as an accelerator.
* Parts per hundred of resin.

TABLE 4—Ratings of Various Epoxy Resin Systems Based on Flexural Strength Retention in Hot Solutions

Media	SYSTEM						
	$BF_3$400	PA	Z	DADS	HET	TETA	CL
25% Hydrochloric Acid	1	7	4	5	6	3	2
25% Sulfuric Acid	3	1	6	3	2	7	4
25% Acetic Acid	3	6	4	5	1	7	2
25% Chromic Acid	7	4	3	6	1	5	2
Trichlorethylene	F	F	4	3	F	1	2
40% Formaldehyde	5	6	4	1	3	F	2
6% Sodium Hypochlorite	7	4	5	2	1	6	3
Distilled Water	2	5	6	3	1	7	4
28.5% Sodium Aluminum Sulfate	4	5	3	2	6	7	1
50% Sodium Hydroxide	4	7	2	3	6	5	1
Average Ratings	36/9	45/9	41/10	33/10	27/9	48/9	23/10
Relative Ratings	4.0	5.0	4.1	3.3	3.0	5.3	2.3

F = failed under these conditions. 7 = poorest of all tested.
1 = best of all tested.

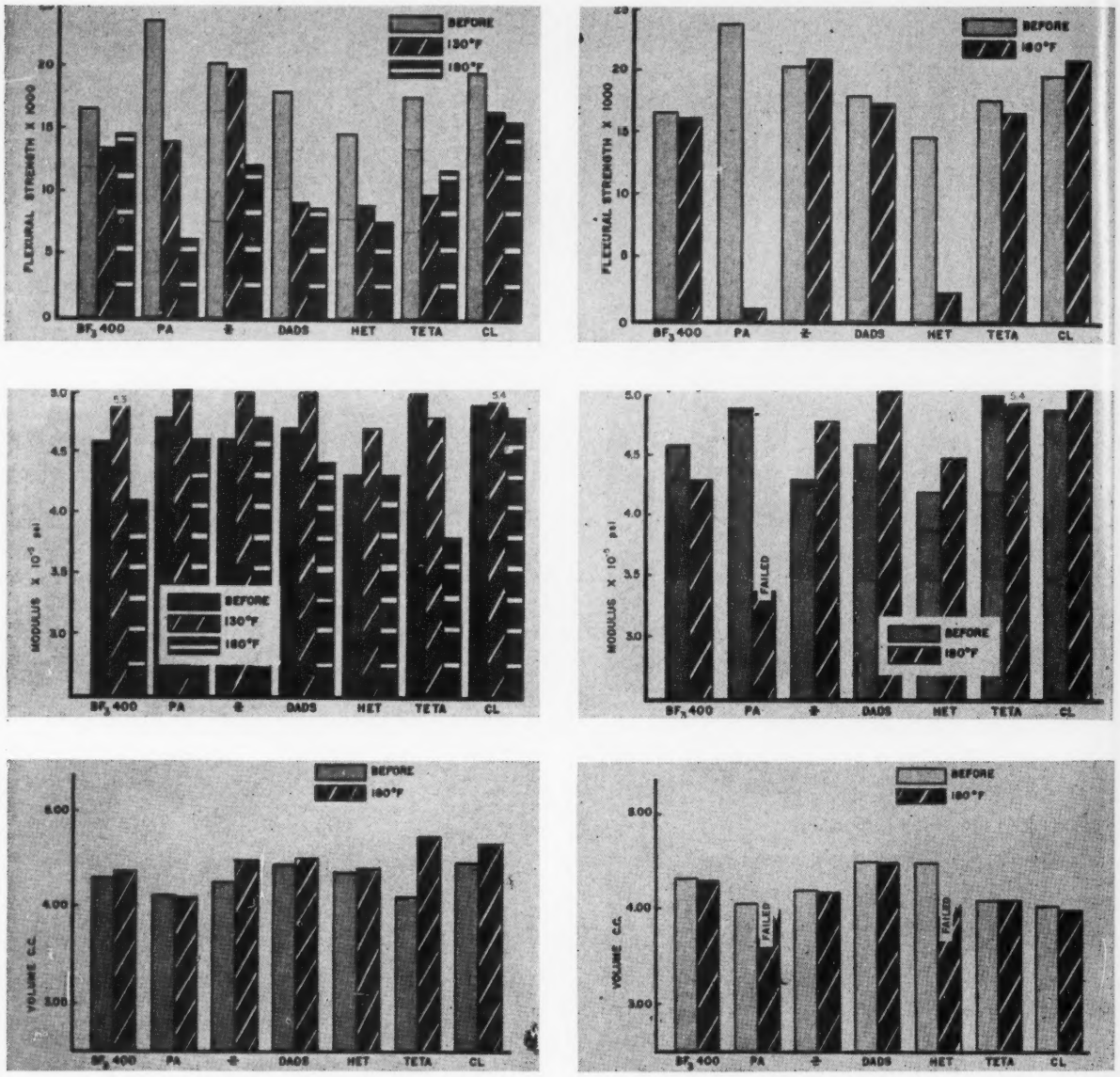


Figure 10—Effect of 25 percent HCl (left three graphs) and 50 percent NaOH (right three graphs) on epoxy resin systems. Graphs shown are, top to bottom: Flexural strength, flexural modulus, and dimensional stability.

while the amines attack the alpha carbon of the epoxy ring.

Generally, the conversion of an epoxy resin to a well cured ether polymer requires the use of a boron trifluoride complex such as the monoethylamine salt. Rather extensive heating is necessary to achieve full cure. The dependence of this reaction upon catalyst concentration is shown in Figure 5. Here heat deflection point measurements are used as criteria for estimating crosslinked density and hence degree of cure.

Tertiary amines do not produce polyether polymers of equivalent heat deflection properties to those obtained with BF_3 complexes. DMP-30[1] and benzyldimethylamine[1] are examples of such amines. These can both be used to achieve room temperature cure with liquid epoxy resins, depending upon the ambient temperature, as well as the thickness of the resin mass. However, the chemical resistance of such polymers is not very good unless heat is used to help the cure. In Figure 6 is shown the effect of concentration on heat deflection point using a tertiary amine salt such as Epon Curing Agent D with a epoxy resin.

2. Condensation With Dibasic Acids and Acid Anhydrides to Form Polyesters

With dibasic acid anhydrides, epoxy rings can form polyesters without loss of water, as shown in Figure 2.

The reaction of epoxy resins with dibasic anhydrides is promoted by the presence of small amounts of tertiary amines or basic salts. It is assumed that these catalysts help in the formation of carboxylate ions and that it is the carboxylate ion which is actually the chain initiator.

The over-all reaction of dibasic anhydride with an epoxy resin in the presence of a base catalyst appears to be primarily the reaction of a carboxyl group and the epoxy ring. If epoxy groups are present in excess, there is indication that they do not react with one another or with hydroxyl materials present until the acid anhydride reaction has been completed. This is possibly due to the fact that no free base is available to catalyze the epoxy-polyether polymerization until the acid in the system has become exhausted.

The anhydride reaction with epoxy resins is less sensitive to concentration than other postulated cure mechanisms. Also, since the combining weights of most anhydrides are greater than those of amines, relatively large concentrations of

[1]Source of all materials used in this work may be found in Appendix 1.

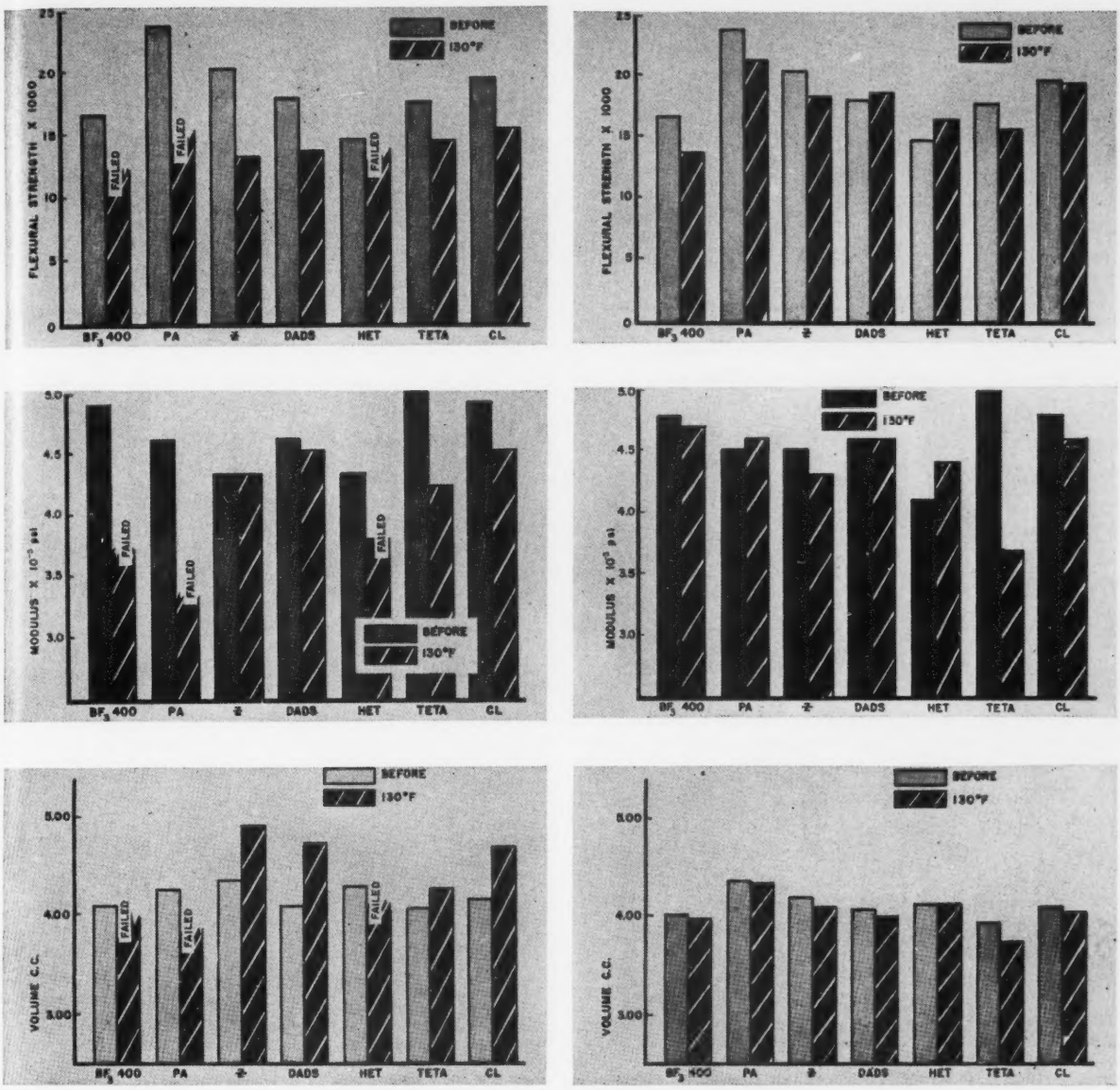


Figure 11—Effect of 100 percent trichloroethylene (left) and 6 percent sodium hypochlorite on epoxy resin systems. Graphs shown are, top to bottom: Flexural strength, flexural modulus, and dimensional stability.

anhydrides are used. In certain cases the amount of anhydride may actually exceed that of the liquid epoxy resin. The cured polymer, therefore, may exhibit properties specifically imparted by the anhydride. For example, an epoxy resin cured with chlorendic anhydride has been found to have flame retardant properties due to the chlorine introduced via the anhydride.

The anhydride epoxy reaction requires rather extensive heating to achieve a complete cure. As far as is known, good properties are not obtainable when room temperature cures are applied. In Figure 7, data for several widely used anhydrides points out the dependence of heat deflection point upon anhydride concentration. After gelation at 250 F for one hour, these systems were postcured for 24 hours at 300 F to develop optimum heat deflection points.

3. Condensation With Diamines to Form Poly(β-hydroxylamines)

Di-primary and secondary amines can condense with epoxy resins through the opening of the epoxy ring by amino hydrogens.

There are indications that aromatic amines like meta phenylenediamine, which are very weak bases, can cure epoxy resins only through some condensation reaction such as above. On the other hand, aliphatic polyamines are sufficiently strong bases to promote polyether formation through either or both of the mechanisms outlined under italic subheading No. 1. Here it is assumed that a primary or secondary amine is first converted to a tertiary amine by successive reactions with epoxy rings.

With amines, stoichiometry is most important if optimum heat deflection points are to be obtained. Aliphatic polyamines such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, aminoethylpiperazine, and others can be utilized to give room temperature cure with liquid epoxy resins. However, only a percentage of potential crosslinking is obtained thereby and heating is recommended to give optimum heat deflection points. In Figure 8 the dependence of cure upon concentration is shown for various aromatic amine-cured systems.

4. Importance of the Final Stages of Cure

The thermoset polymer obtains its major properties of infusibility and insolubility in proportion to the degree of

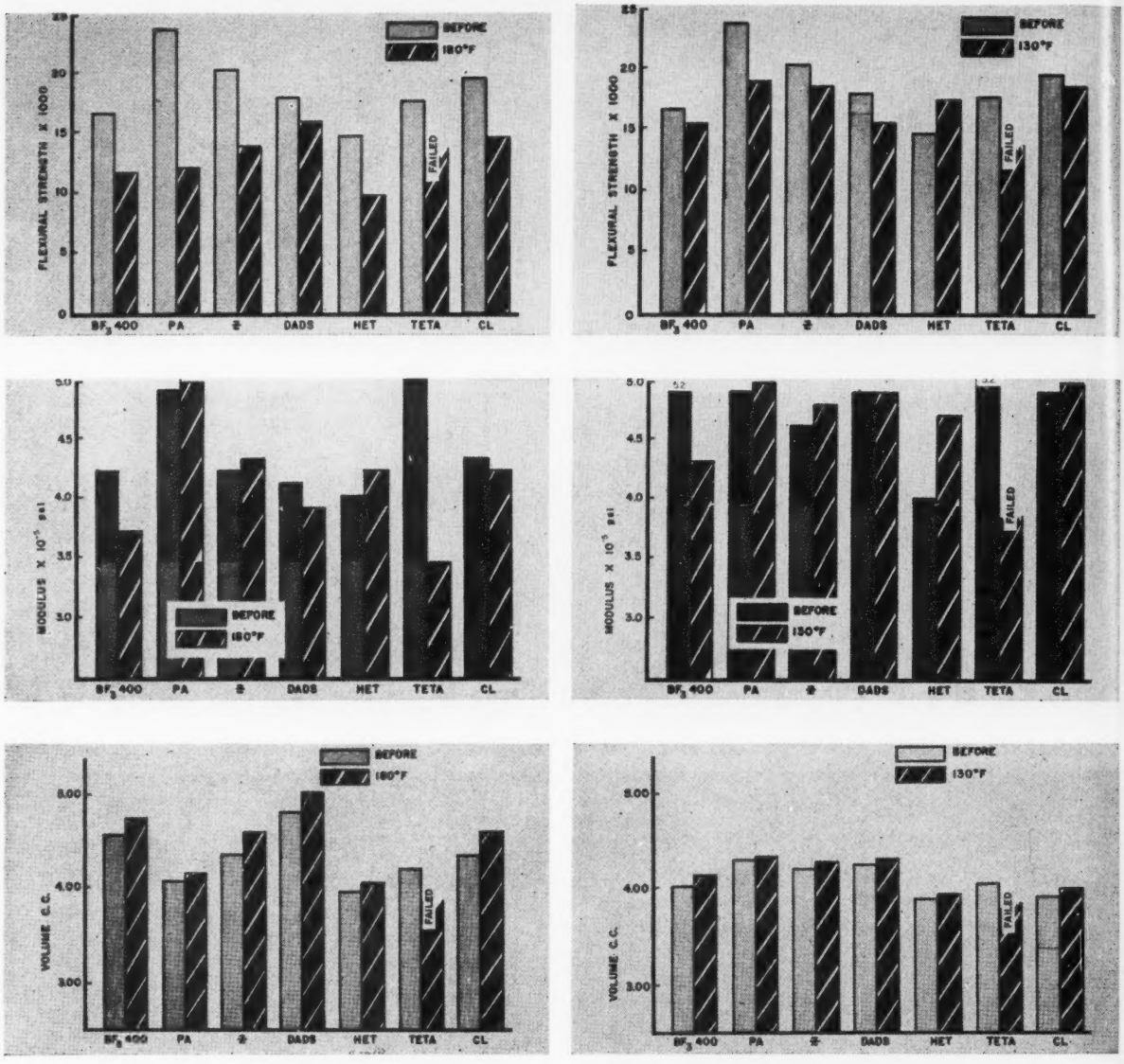


Figure 12—Effect of 40 percent formaldehyde (left three graphs) and 25 percent acetic acid (right three graphs) on epoxy resin systems. Graphs shown are, top to bottom: Flexural strength, flexural modulus and dimensional stability.

cross-linking that occurs in the final stages when the large polymer molecules are combined to form macromolecules. Experiments have shown that after the reaction has essentially ceased (as indicated by infrared analysis for epoxy groups) the hot-hardness of the cured resin is still increasing. It is in recognition of this fact that post cures or afterbakes are so often recommended when the maximum in chemical resistance or elevated temperature strength is desired.

The influence of continued heating upon heat deflection points are indicated by the shaded areas in Figures 5, 6, and 8.

In Figure 5, data are plotted for cures of BF_3 monoethylamine complex-epoxy resin systems which appear to be optimum in terms of heat deflection point. The cure cycle included three hours at 250 F plus one hour at 400 F. Extension of the post cure to eight hours at 400 F produced a slight increase in heat deflection point, below the three phr (parts per hundred of resin) BF_3 monoethylamine concentration level, and in a slight decrease above the three phr concentration level, as indicated in the shaded area.

In Figure 6 data are plotted for tertiary amine salt-epoxy resin systems cured at 150 F for three hours, and 267 F for one hour. This is curve A. In curve B, data are given for the same systems which have been given an additional post cure of four hours at 400 F.

In Figure 8, data are plotted for cures of aromatic polyamine-epoxy resin systems. With Curing Agent Z, the cure cycle consisted of two hours at 176 F, and one hour at 400 F. Extensive post curing at this high a temperature (i.e., 400 F) is not recommended for the Curing Agent Z-epoxy resin system. With a 300 F post cure for 24 hours, however, increases in heat deflection point take place as shown in the shaded area. In the case of diaminodiphenylsulfone-epoxy resin systems, data are plotted for a cure of two hours at 400 F. Post cures of 32 hours at 400 F produced heat deflection point improvements as shown by the shaded area on the curve. In all cases 1 percent of BF_3 monoethylamine complex was used as an accelerator in diaminodiphenylsulfone-epoxy resin systems, hence considerably less than stoichiometric amounts (32 phr) were effective in producing high heat deflection points.

Experimental

A liquid epoxy resin having a weight per epoxide of 194 grams (Epon 828) was blended with various liquid amines, solid and liquid anhydrides, and with a BF_3 complex. The mixtures were prepared at temperatures where dissolution of the solids took place readily or at room tem-

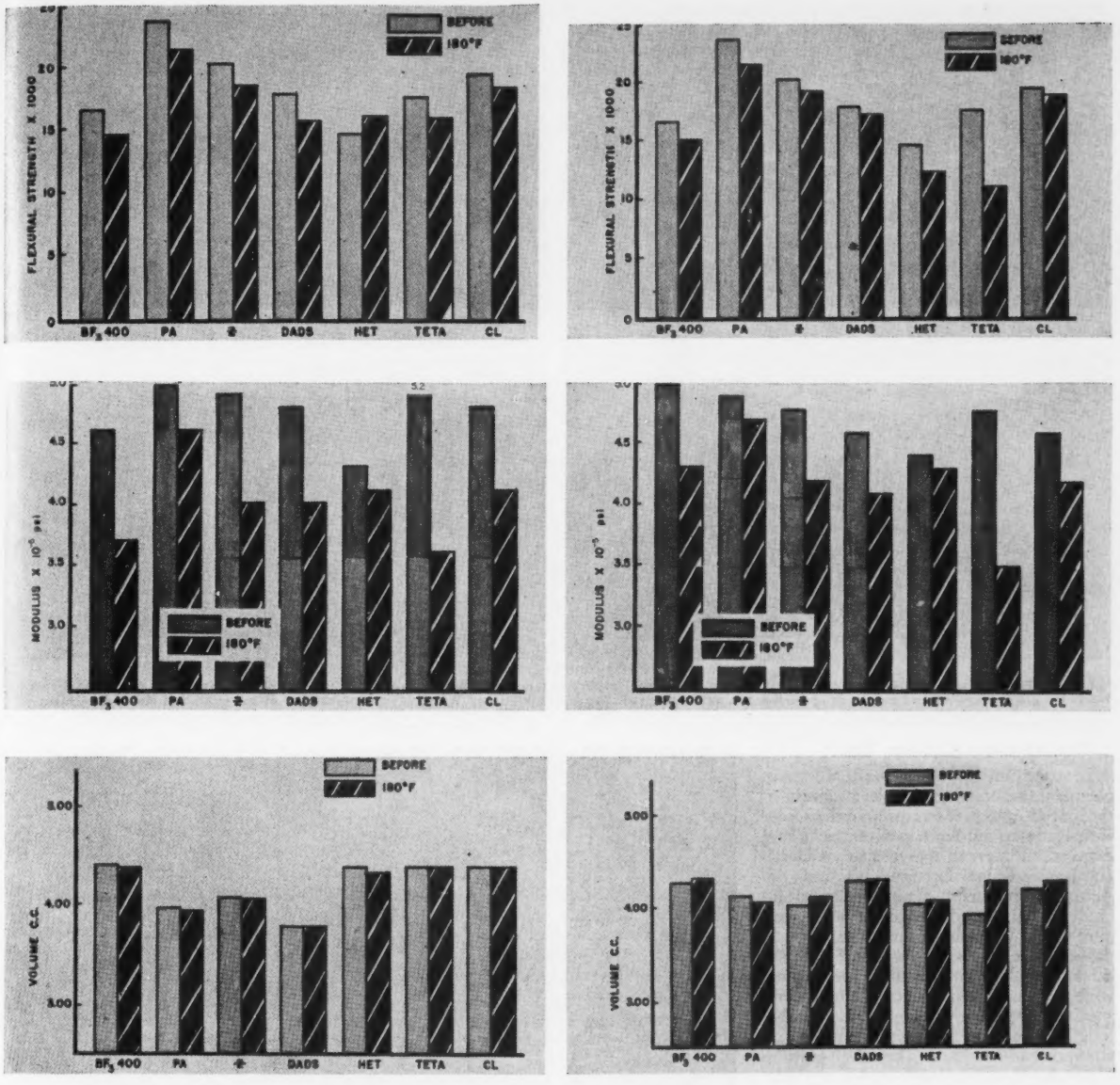


Figure 13—Effect of 25 percent chromic acid (left three graphs) and 28.5 percent sodium aluminum sulfate (right three graphs) on epoxy resin systems. Graphs shown are, top to bottom: Flexural strength, flexural modulus, and dimensional stability.

perature in the case of the liquid curing agents. After thorough blending the mixtures were poured between sheets of plate glass which had previously been coated with Garan 225 (Ram 225) release agent. Castings ⅛ inch thick, and approximately 14 inches square were thus prepared by inserting a rubber shim between 16 inch square glass plates holding the entire set-up together with clamps. Each of the various systems was cured according to time and heat cycles required for optimum cure. One system utilizing a room temperature curing agent was allowed to cure for 21 days at room temperature. The resin systems investigated together with cure conditions for each are given in Table 2.

After cures of each system were complete, the sheets were cut into flexural test specimens ½ inch wide, and 4 inches long. These were then weighed in air and water to determine weight and density. They were also measured with a micrometer and calipers to establish dimensions and marked for future identification.

Immersion Tests

Five samples of each system were then evaluated for flexural strength and modulus[2] and five were immersed in each of the following test solutions at the temperatures noted for 180 days:

25 percent Acetic Acid at 130 F
Trichlorethylene at 130 F
6 percent Sodium Hypochlorite at 130 F
Distilled Water at 130 F
50 percent Sodium Hydroxide at 180 F
25 percent Sulfuric Acid at 180 F
40 percent Formaldehyde at 180 F
25 percent Chromic Acid at 180 F
28 percent Sodium Aluminum Sulfate at 180 F
25 percent Hydrochloric Acid at 130 F and 180 F

All solutions were made to known strength and renewed periodically. The immersion tests were carried out in round, screw cap, seven ounce bottles with polyethylene sheet gaskets in the covers. These bottles were immersed in turn in water baths at 130 F and 180 F.

At the end of this test period the samples were removed from the test solutions, immersed in cold water, wiped dry and again evaluated for flexural strength and modulus. They were also weighed in the air and water to determine weight, density, and volume changes.

[2]According to test methods given in Appendix 2.

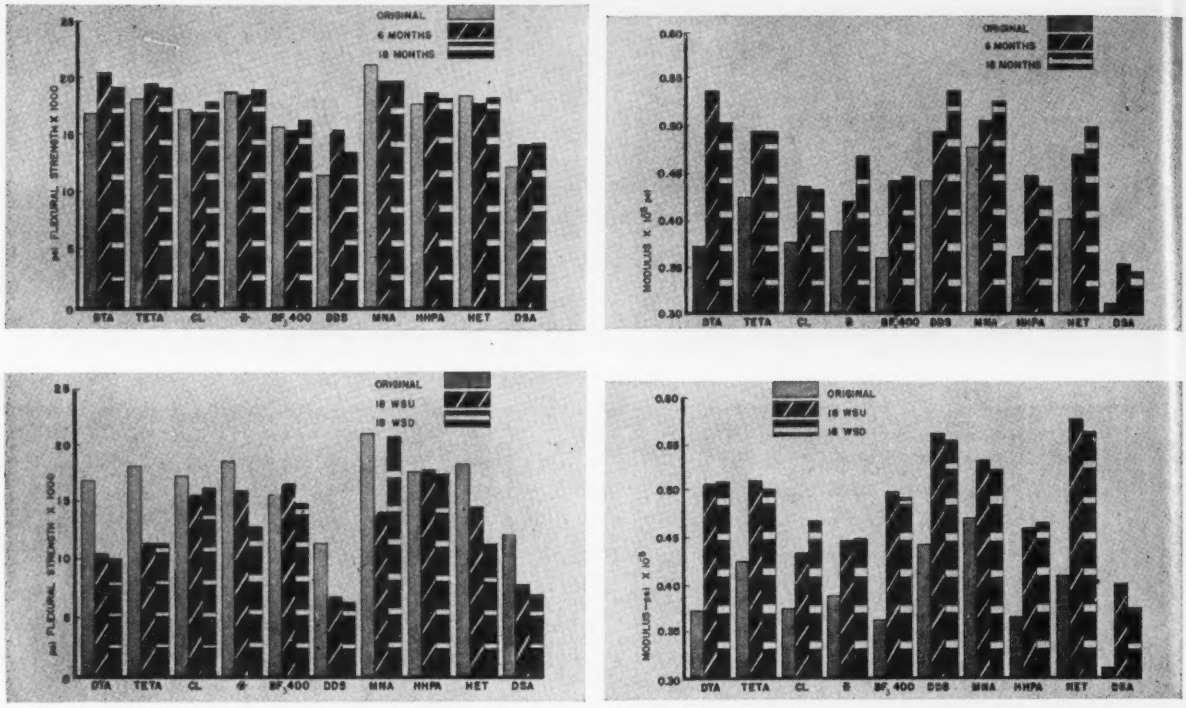

ORIGINAL
6 MONTHS
18 MONTHS
psi FLEXURAL STRENGTH X 1000
MODULUS X 10⁵ psi
DTA TETA CL B BF3 400 DDS MNA HHPA HET DSA
ORIGINAL
18 WSU
18 WSD
psi FLEXURAL STRENGTH X 1000
MODULUS—psi X 10⁵
DTA TETA CL B BF3 400 DDS MNA HHPA HET DSA

Figure 14—Effect of outdoor exposure on flexural strength (left two graphs) and flexural modulus (right two graphs) of epoxy resin systems. Samples in two top graphs were masked and those in bottom two were unmasked. The letters WSU and WSD refer to the position of the weathered side during test.

Outdoor Exposure Tests

In addition to the investigation of chemical resistance, sample castings of the cured epoxy resins prepared as previously described were put on racks and exposed outdoors at the company's Union (N. J.) Technical Service Laboratory. Actual resin-curing agent systems included in this study, together with their cure cycles were shown in Table 3.

Six castings of each system ⅛ inch thick, 6 inches wide, and 12 inches long were prepared and one cut into flexural specimens ½ inch wide and 4 inches long. These were evaluated for flexural strength and modulus. The other castings were placed on exposure racks at 45 degrees to the south according to ASTM D 1014-51 and D 1435-58. The top quarter of the panels were masked with aluminum foil.

Discussion of Results

Immersion Testing

The usual methods which are used to evaluate the corrosion resistance of metals (i.e., inches penetration per year) are not meaningful when applied to thermosetting resins. Neither are *weight gains,* which are generally used as criteria for evaluating the performance of plastics. For it has been observed that chemical attack may in certain instances *dissolve low molecular weight fractions* of thermosetting resin polymers while the higher molecular weight fractions actually absorb the chemical solution. Hence the over-all weight change is actually a summation of both processes and does not necessarily reflect performance of the polymer.

It appears that corrosion resistance of resins may be more realistically delineated by using as parameters such factors as changes in flexural properties and dimensions. The most convenient and reliable method of measuring the physical strength of plastics is the flexural test procedure. Hence this is the one that has been employed throughout (as outlined in Appendix 2). The original dimensions of each sample were used for calculating flexural strength and modulus after 180 days exposure.

Values for flexural strength, modulus and volume changes are shown in Figures 9, 10, 11, 12, and 13. References to this data brings out the following:

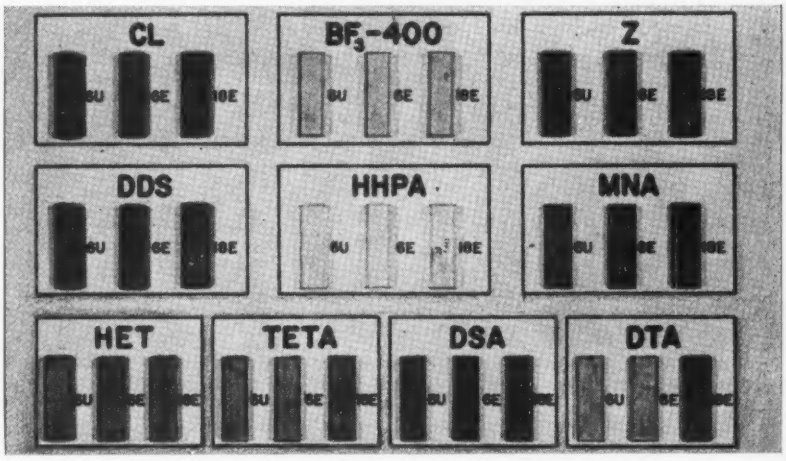


Figure 15—Flexural specimens after exposure for indicated times. The letter U refers to unexposed or masked specimens and the letter E to exposed specimens.

(A) Resistance to Distilled Water

All epoxy resin systems have good dimensional stability and retain flexural strength when exposed to water at 130 F. BF_3 cured epoxy resins appear best in this regard. The flexural modulus of a room temperature aliphatic amine cured polymer dropped considerably in this test; others showed little change.

(B) Resistance to Mineral Acids

Anhydride cured epoxy resins show excellent resistance to 25 percent sulfuric acid at 180 F. BF_3 cured epoxies are almost as good whereas amine cured epoxies are only mediocre in such solu-

tions. In the case of hot 25 percent hydrochloric acid, however, aromatic amines tend to produce the best properties, BF_3 complexes second best, and anhydrides very poor properties. Room temperature aliphatic amine cured epoxies swelled considerably in both types of acid, softened, and lost a good deal of flexural strength.

(C) Resistance to 50 Percent Caustic Soda

Amine cured epoxies exhibit excellent resistance to hot caustic soda and BF_3 complexes are equally effective in producing resistant polymers. Anhydride cured epoxy resin failed after 180 days immersion at 180 F.

(D) Resistance to Chlorinated Solvents

Of the samples exposed to trichlorethylene, only amine cured specimens were able to survive the testing at 130 F, retaining about 80 percent of their original flexural strength but swelling considerably in the process. Heat cured aromatic amine epoxies were considerably better than room temperature aliphatic amine cured epoxies in this respect.

(E) Resistance to Bleach Solution

Aromatic amine cured epoxy resin castings showed the best resistance to warm 6 percent sodium hypochlorite solution. Other specimens appeared to be on a par and almost as good, with the exception of the room temperature aliphatic amine cured samples which softened considerably in this test.

(F) Resistance to Formaldehyde

Forty percent aqueous formaldehyde solution at 180 F caused all of the test castings to swell and to lose flexural strength. A room temperature amine cured epoxy resin system actually failed in this service. Aromatic amine cured systems showed the least loss of strength and anhydrides the greatest.

(G) Resistance to Organic Acids

Room temperature amine-cured epoxy resin failed on immersion in 25 percent acetic acid at 130 F. A chlorendic anhydride cured epoxy resin actually developed more strength in this service. Other cured systems maintained original dimensions and lost only small amounts of their flexural strength.

(H) Resistance to Plating Solutions

Most systems performed well in 25 percent chromic acid at 180 F as far as maintenance of dimensions is concerned. Flexural strength losses were low but rather severe losses in flexural modulus were noted in every case. Anhydride cured epoxies showed the least loss in modulus.

(I) Resistance to Alum Solution

Room temperature aliphatic amine-cured epoxies do not show much resistance to 28.5 percent sodium aluminum sulfate as evidenced by 30 percent loss of flexural strength, swelling and softening. Aromatic amine and BF_3 complexes apparently provide the most resistant polymers.

The various systems can be rated as shown in Table 4 according to their retention of flexural properties. The most resistant is rated 1, and the least resistant is rated 7. In summation, the best all around system appears to be a m-phenylenediamine cured epoxy resin.

Outdoor Exposure

Flat sheets of each epoxy resin system were put on exposure racks, as previously described, in March of 1958 at the company's Union (N. J.) Laboratory. In September of 1958 one sheet of each resin system was cut into flexural specimens and evaluated. In view of the fact that chalking was noted on the surface of certain sheets after 18 months exposure all were evaluated for flexural strength with the weathered side up and also with the weathered side down. A comparison of flexural properties is shown graphically in Figure 14. The letters WSU and WSD refer to the position of the weathered side during test.

Masked specimens showed little change in ultimate flexural strength upon 18 months outdoor exposure. The moduli, however, increased considerably during this period.

In unmasked specimens, however, some losses in flexural strength were incurred, while at the same time all moduli increased. Notably affected by such an environment were aliphatic amine-cured epoxy resin systems, diaminodiphenylsulfone epoxy resin systems and dodecenylsuccinic anhydride epoxy resin systems.

Least affected of all systems appears to be the anhydride cured epoxy resins. Based purely upon flexural properties in unmasked samples, the resistance to weathering of the various systems can be rated as follows:

1. Hexahydrophthalic anhydride cured
2. Nadic methyl anhydride cured
3. m-Phenylenediamine cured
4. Boron trifluoride—monoethylamine
5. Epon curing agent Z cured
6. Triethylenetetramine cured
7. Chlorendic anhydride cured
8. Diethylenetriamine cured
9. Dodecenylsuccinic anhydride cured
10. Diaminodiphenylsulfone cured

In Figure 15 are shown actual pictures of the flexural specimens after exposure for the indicated times. The letter U refers to unexposed or masked specimens, the letter E to exposed specimens. The numbers refer to months of outdoor exposure.

Conclusion

In this study pure epoxy resin castings have been evaluated in various corrosive environments. In actual usage the resin is normally mixed with inert fillers and applied to a substrate such as steel, wood, or concrete. It also may be reinforced with fiberglass to produce structural laminates which have proven to be extremely useful in the form of pipes or tanks. In either case, considerably less loss in physical strength can be expected from each particular system than under the test conditions imposed herein. Also, in actual operation resin linings are exposed to chemical attack from one direction only, and this is a much less severe condition to meet. However, this study can be interpreted as an accelerated screening of liquid epoxy resins systems.

1. Heat cured m-phenylenediamine epoxy resin systems appear to offer the best all around resistance to immersion in hot chemical solutions with heat-cured BF_3 complex epoxy resin systems a close second.

2. Anhydride cured epoxy resins offer specifically good resistance to hot sulfuric acid but do not perform as well in hot hydrochloric acid. As might be expected, in view of their preponderance of ester groupings, they are quite susceptible to attack by caustic soda, and by chlorinated solvents.

3. Aliphatic amine-cured epoxy resins without an elevated temperature cure are considerably less resistant than other epoxy polymers to chemical attack from mineral acids, organic acids, aldehydes, chlorinated hydrocarbons, and bleach solution. They appear to be resistant to sodium hydroxide, water, alum solution and chromic acid.

4. Heat cured hexahydrophthalic anhydride epoxy resin combinations offer the best resistance to outdoor weathering.

Acknowledgments

The author wishes to thank Messrs. R. W. Pease, P. A. Teliha, J. A. Ditzler, P. D. Jones, R. J. Endler, and others of the Union Technical Service Laboratory, for their aid in preparing the data presented in this paper.

APPENDIX 1—Source of Materials Used In This Study

Material	Source
Epoxy Resin—Epon 828	Shell Chemical Company
Curing Agents:	
Boron Trifluoride—Monethylamine	Allied Chemical Corporation General Chemical Division
	Harshaw Chemical Company
Benzyldimethylamine	Sumner Chemical Company
Diaminodiphenylsulfone	Roussel Chemical Company
Diethylenetriamine	Union Carbide Chemicals Company
Dodecenylsuccinic Anhydride	Allied Chemical Corporation National Aniline Division
Chlorendic Anhydride	Hooker Chemical Corporation
Hexahydrophthalic Anhydride	Allied Chemical Corporation National Aniline Division
Nadic Methyl Anhydride	Allied Chemical Corporation National Aniline Division
m-Phenylenediamine	E. I. du Pont de Nemours and Co., Incorporated
Phthalic Anhydride	Monsanto Chemical Company
Triethylenetetramine	J. T. Baker Chemical Company
DMP-30	Rohm and Haas Company
Garan 225 (Ram 225)	Ram Chemicals Gardena, California

Appendix 2

All modulus of flexibility testing was done on the Instron Universal Tester. Rate of crosshead motion = .05 inch per minute. Span maintained at 2.5 inches. All test values based upon original specimen dimensions.

1. Modulus of Flexibility $= E\frac{625\ S^3P^2}{Wd^3IR_sP_c}$

Where S = Specimen span length in inches
P = Load in pounds applied to specimen
R_s = Rate of load application in inches/minute
P_c = Full machine load scale in pounds
d = Specimen thickness in inches
W = Specimen width in inches
I = Integrator number obtained in test at counts/minute. This number is a true measure of the area under a stress/strain curve.

2. Maximum fiber stress = psi $=\frac{3P \times S}{2Wd^2}$

DISCUSSION

Question by John Delmonte, Furane Plastics, Inc., Los Angeles, Calif.:

For a given class of curing agents for epoxies do you find any relations between the ultimate heat distortion temperature and the chemical resistance of the cured system?

Reply by R. L. DeHoff:

The chemical resistance of a cured epoxy resin system certainly appears to be related to heat deflection point. Thus among a class of curing agents such as anhydrides, Nadic methyl anhydride and pyromellitic appear to offer superior properties in cured epoxy polymers as compared to Het anhydride. Het anhydride likewise produces properties superior to those of phthalic anhydride. Nadic methyl and pyromellitic anhydride cured epoxy resin systems have heat deflection points approaching 250 C, Het anhydride cured systems about 200 C, and phthalic anhydride cured systems about 150 C.

Question by E. C. Whittier, Pittsburgh Coke and Chemical Co., Pittsburgh, Pa.:

Does a post heat cure of the aliphatic amines such at Teta improve the properties of the cured system?

Reply by R. L. DeHoff:

The post cure of an aliphatic amine-cured epoxy resin system will certainly result in an improvement of properties.

Question by William C. Hodges, Mountain View, Calif.:

Would not the use of an amine adduct such as curing agent "U" especially if combined at elevated temperatures (180 F) with the resin, have demonstrated substantially better properties than the Teta cured system and would not this have been a better representative of an ultimate room temperature cure system to compare with the other baked systems shown?

Reply by R. L. DeHoff:

It is likely that the use of curing agent U in place of Teta might have given better properties in a room temperature cured system. However, Teta appears to be of the most interest in room temperature curing of the purer, more viscous liquid epoxy resins because of the low viscosity it imparts to the system. We agree that in using such systems at 180 F, the viscosity problem is eliminated but the pot life will also be sharply reduced.

Any discussion of this article not published above will appear in June, 1961 issue.

Corrosion-Erosion of Sensitized AISI Type 304 Stainless Steel In a Thorium Dioxide-Uranium Trioxide Slurry*

By D. C. VREELAND

Abstract

Corrosion test loops were employed in evaluating the corrosion-erosion of sensitized AISI Type 304 stainless steel in a thorium dioxide-uranium trioxide slurry. It was found that sensitized, non-pickled Type 304 stainless steel was not attacked intergranularly and exhibited about the same corrosion rate as as-received Type 304. Type 304 stainless steel, sensitized and pickled, was attacked at appreciably higher rates than as-received Type 304 or than sensitized, non-pickled Type 304; however, when a layer of metal which had been corroded intergranularly by the pickling solution was removed by the action of the slurry, the attack by the slurry diminished.

6.2.5, 8.4.5, 4.3.3, 3.2.2, 3.5.3

Introduction

SENSITIZED AISI Type 304 stainless steel was tested as part of a program to evaluate the corrosion-erosion behavior of materials in a thorium dioxide—uranium trioxide slurry considered for use as fuel, moderator, and coolant for a nuclear-reactor power plant.[1] Four dynamic-testing loops were built to make possible the checking of the corrosion-erosion behavior in slurry of various materials that might be used in constructing the plant, and of observing slurry-handling properties.

As is known, sensitization of austenitic stainless steel may occur during welding operations and such steel may be subject to intergranular corrosion in certain environments. Sensitization and the behavior of sensitized stainless steel in various corrosive media other than flowing ThO_2 - UO_3 slurries have been discussed by others.[2,3]

About the Author

D. C. VREELAND, a member of NACE and ASM, is associated with the Applied Research Laboratory, United States Steel Corporation, Monroeville, Pennsylvania. As head of the Applications Section, Corrosion Technology Division, he is concerned with corrosion research on stainless, alloy, and carbon steels. Prior to joining U. S. Steel, he was with Westinghouse Electric Corporation, Electronic Tube Division, and also Oak Ridge National Laboratory. He has a B.S. from Antioch College and an M.S. in metallurgy from Ohio State University.

Apparatus and Procedure

Figure 1 is a photograph of one of the corrosion-test loops during operation. These loops can operate at a temperature of 600 F and at a pressure of 2000 psi. The main lines were constructed of 3-inch Types 304 and 347 stainless steel pipe. Specimen holders are designed so that specimens approximately 2 inches by ¾ by ⅛ of an inch can be mounted in interior channels through which the slurry flows during operation of the loop.

Figure 2 shows an open holder containing corrosion-erosion specimens. Two types of holders were used in this program: (1) a constant velocity type, in which the channel in the holder through which the slurry flows is of constant dimensions, and (2) a variable velocity type, in which the channel in the holder gradually reduces in size so that the velocity of the slurry is increased as it passes through the holder.

Test specimens were prepared from Type 304 and 347 stainless steel sheet stock by sawing oversize and then machining the edges to remove the sawed areas. Prefilmed specimens (i.e., specimens exposed to high-temperature water to develop an oxide film before exposure to slurry), were treated for 24 to 72 hours in an environment of demineralized water in the loop at 580 F and 1700 psi, with oxygen concentration ranging from 600 to 1000 ppm. Sensitized specimens were prepared by heating in hydrogen or argon atmosphere (impure) for 4 hours at 1250 F. It was thought that if the steel had satisfactory corrosion behavior after sensitizing for four hours at 1250 F it would be expected to be satisfactory after the much less drastic sensitizing that would occur during a welding operation. Oxide that formed on the specimens during sensitization was removed by either of two methods: (1) grinding, or (2) pickling the specimens in HNO_3-HF solution.

Pickling was used for removing oxide from some of the sensitized test specimens because acid pickling solutions were considered as one of several possible agents for cleaning other test loops after construction. Specimens were measured with a micrometer, washed, rinsed in acetone, dried, weighed, and loaded into specimen holders which were then installed in a loop. During the tests the specimens were electrically insulated from the specimen holder and from each other by means of Teflon tape.

After the tests, the specimens were washed free of adhering slurry, electrolytically stripped of oxide films, dried, and weighed. Corrosion rates were calculated from weight loss after the oxide film was stripped off. Selected specimens were examined metallographically. Table 1 shows the composition of the materials tested.

High-purity water (500,000 ohm-cm) was used in making the slurry. Oxide used in making the slurry was high purity ThO_2 and UO_3.

Sensitized and pickled Type 304 specimens subjected to variable velocity conditions were exposed in Loop A, and specimens subjected to constant velocity conditions were exposed in Loop B. For comparison purposes, Loop B also included coupons of Types 304 in "as-received" and in prefilmed conditions. The conditions during loop operation for tests on sensitized Type 304 specimens were as follows:

A Loop:

Mean slurry concentration—320 gm ThO_2 and 11.7 gm UO_3 per liter
Temperature—580 F
Pressure—1650 psig
Oxygen—770 ppm
Slurry velocity past coupons—25 to 88 fps
Time of test—1000 hours

B Loop:

Mean slurry concentration—330 gm ThO_2 and 12.2 gm UO_3 per liter
Temperature—580 F

★ Submitted for publication March 28, 1960.

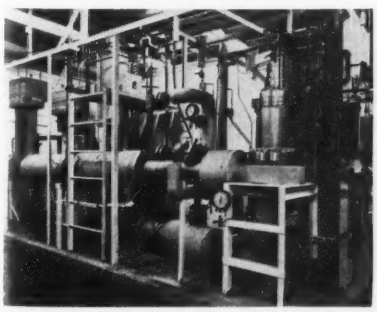


Figure 1—Corrosion test loop.

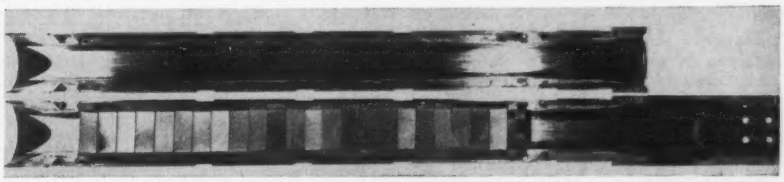


Figure 2—Opened specimen holder with test specimens.

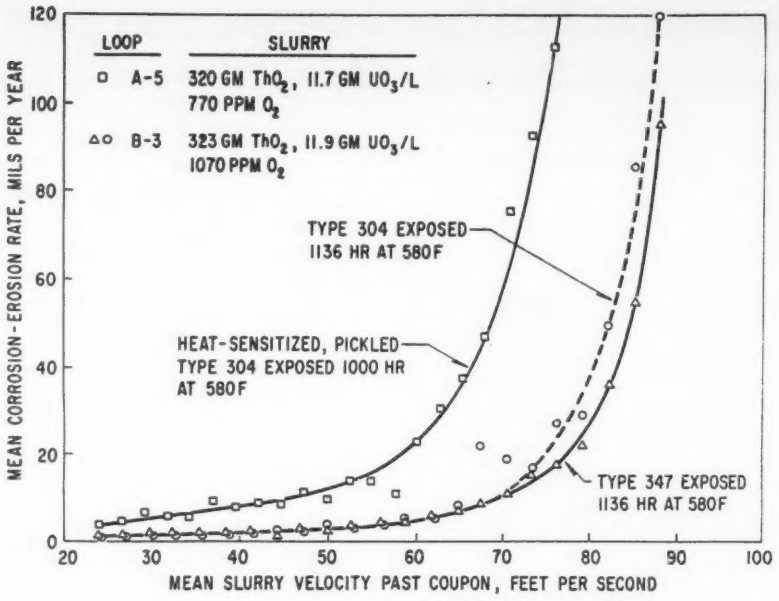

LOOP
SLURRY
□ A-5 320 GM ThO_2, 11.7 GM UO_3/L 770 PPM O_2
△○ B-3 323 GM ThO_2, 11.9 GM UO_3/L 1070 PPM O_2
TYPE 304 EXPOSED 1136 HR AT 580F
HEAT-SENSITIZED, PICKLED TYPE 304 EXPOSED 1000 HR AT 580F
TYPE 347 EXPOSED 1136 HR AT 580F
MEAN CORROSION-EROSION RATE, MILS PER YEAR
MEAN SLURRY VELOCITY PAST COUPON, FEET PER SECOND

Figure 3—Influence of velocity on mean corrosion-erosion rate.

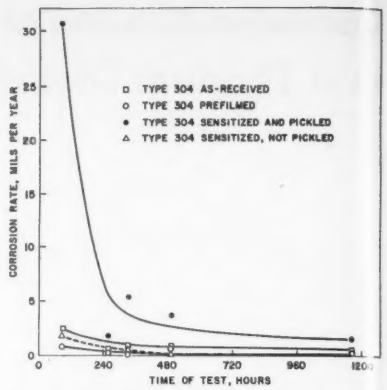

□ TYPE 304 AS-RECEIVED
○ TYPE 304 PREFILMED
• TYPE 304 SENSITIZED AND PICKLED
△ TYPE 304 SENSITIZED, NOT PICKLED
CORROSION RATE, MILS PER YEAR
TIME OF TEST, HOURS

Figure 4—Results of loop test comparing sensitized and unsensitized Type 304 stainless steel.

TABLE 1—Composition of Test Materials, Percent

Material	ELEMENT, PERCENT							
	C	Mn	P	S	Si	Ni	Cr	Cb
Type 304	0.05	1.34	0.034	0.015	0.47	9.34	18.85	Not determined
Type 347	0.06	1.52	0.025	0.017	0.83	10.35	17.42	0.87

Pressure—1700 psig
Oxygen—none
50 psi N_2 overpressurization
Slurry velocity past coupons—28 fps
Time of test—89, 257, 330, 494 or 1170 hours

Results and Discussion

These tests show that sensitized Type 304 stainless steel which has been descaled by pickling in HNO_3-HF solution has a higher corrosion-erosion rate when exposed in a test loop than does as-received, prefilmed, or sensitized non-pickled Type 304 stainless steel.

Figure 3 shows results obtained from exposure of sensitized, pickled, Type 304 stainless steel in a variable velocity holder for the Loop A-5 run, compared with typical results obtained for as-received Types 304 and 347 from the Loop B-3 run in which operating conditions were similar to the A-5 run. It is apparent that the corrosion-erosion rate for sensitized and pickled Type 304 is higher, especially at higher velocities, than are the corresponding rates for as-received Type 304 or 347.

Figure 4 shows corrosion-erosion rates obtained in another Loop B run in constant velocity holders at various time intervals for sensitized and pickled Type 304 compared to as-received Type 304, prefilmed Type 304 and sensitized non-pickled Type 304. The points on the curves in Figure 4 are the means of rates for at least four test specimens.

The curves in Figure 4 show that the corrosion-erosion rates for sensitized and pickled steel are significantly higher at lower testing times than are rates for as-received, or prefilmed, or sensitized non-pickled Type 304. There is no appreciable difference in corrosion rates for as-received, prefilmed, or sensitized non-pickled Type 304.

Observation of the sensitized pickled specimens revealed that their surfaces had been roughened by the pickling, and that after exposure in a loop the surfaces appeared to be further roughened. Metallographic examination revealed the reason for the corrosion-erosion behavior of the sensitized pickled stainless steel. Figure 5 shows the microstructure of the as-received Type 304 stainless steel and Figure 6 shows the microstructure of the sensitized steel. Note the carbide particles, indicative of the sensitized condition, that have formed at the grain boundaries.

Figure 7 shows the microstructure of steel that has been sensitized and then pickled in HNO_3-HF. Note that intergranular attack and roughening of the surface have been caused by the pickling. Figure 8 shows the microstructure of steel that was sensitized, pickled, and then exposed to B Loop environment for 89 hours in a constant-velocity holder. Apparently because of the velocity of the slurry and the localized turbulence formed in the slurry stream (a result of roughened surface of the specimens that is caused by pickling), the surface layers of the sensitized pickled specimens have eroded away; this leads, of course, to high erosion-corrosion rates. Figure 4 shows that as the time of test increased to 1170 hours, the corrosion-erosion rate of the sensitized, pickled steel decreased to rates comparable with the rates for as-received, prefilmed, or sensitized non-pickled steels.

Figure 9 shows the microstructure of sensitized, pickled steel that was exposed in B Loop for 1170 hours. Apparently the layer of steel that had been attacked by the HNO_3-HF pickling bath has eroded away, but little or no further attack has occurred. This would account for the decrease of corrosion-erosion rate with time of exposure for sensitized pickled steel. However, at higher velocities, see Figure 3, for times of approximately 1000 hours the corrosion-erosion rate of sensitized pickled steel remained significantly higher than rates for as-received Type 304 or 347 stainless steel. Apparently at these higher velocities, eddying, and thus corrosion-erosion rate, are increased by the rough, pickled surface.

Figure 4 shows that the corrosion-erosion rate of sensitized non-pickled Type 304 stainless steel is comparable to rates obtained for as-received Type 304. Metallographic examination of sensitized non-pickled steels exposed in the loops failed to reveal any sign of intergranular corrosion.

Figure 10 is a photomicrograph of a sensitized non-pickled specimen that was exposed in a loop for 89.2 hours. Carbides, indicative of sensitization, are visible at the grain boundaries, but no intergranular attack or other type of corrosive attack is visible. Similar results for sensitized non-pickled 18-8 stainless steels have been reported for high-purity water environments.[4]

Conclusions

1. Sensitized non-pickled Type 304 stainless steel was attacked at approximately the same rate as was as-received Type 304 in test loop systems at a velocity of approximately 28 fps. Sensitized non-pickled steel was not attacked intergranularly in PAR loops.

2. Type 304 stainless steel, sensitized and pickled in HNO_3-HF, was attacked

Figure 5—Microstructure of as-received Type 304 stainless steel. Etched electrolytically in oxalic acid, 400X.

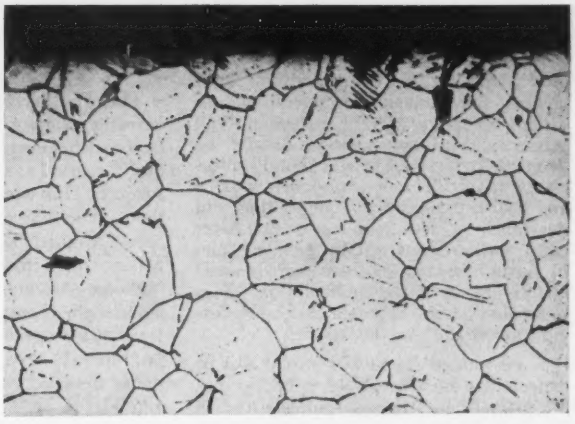


Figure 6—Microstructure of Type 304 stainless steel sensitized for four hours at 1250 F. Note carbide particles at grain boundaries. Etched electrolytically in oxalic acid, 400x.

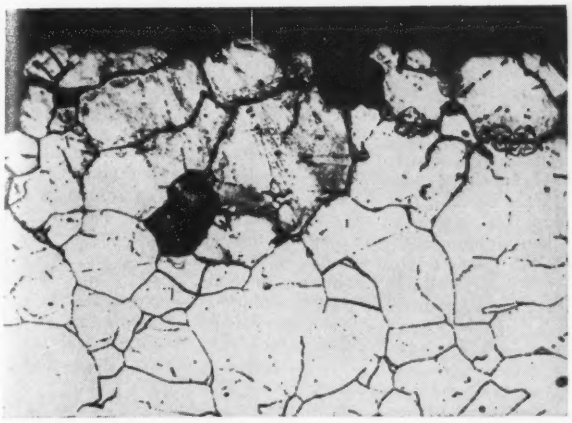


Figure 7—Microstructure of Type 304 stainless steel sensitized for four hours at 1250 F, pickled in HNO_3-HF. Note intergranular attack and roughening of surface caused by pickling. Etched electrolytically in oxalic acid, 400X.

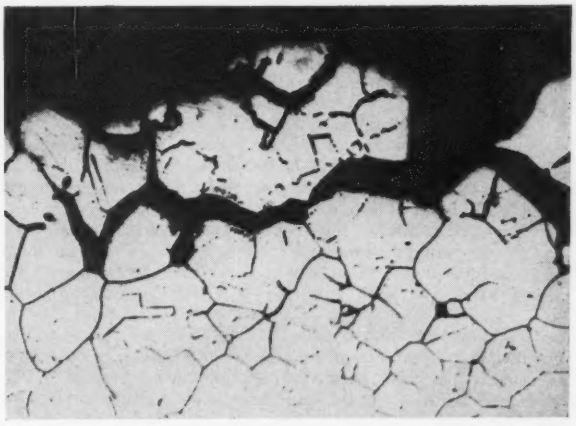


Figure 8—Microstructure of Type 304 stainless steel sensitized for four hours at 1250 F, pickled in HNO_3-HF, and exposed in loop for 89 hours. Note "lifting" of grains of metal which were apparently attacked by pickling solution. Etched electrolytically in oxalic acid, 400x.

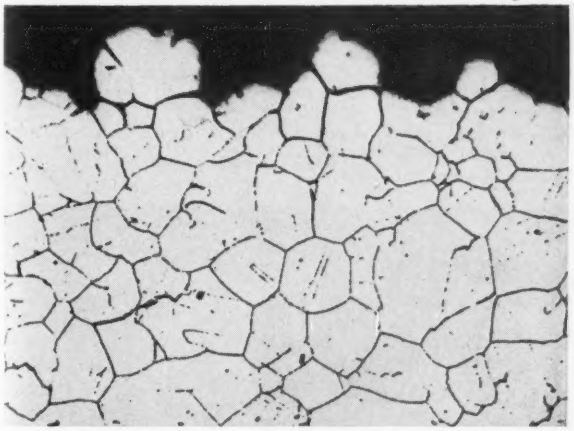


Figure 9—Microstructure of Type 304 stainless steel sensitized for four hours at 1250 F., pickled in HNO_3-HF, and exposed in loop for 1170 hours. Note how most of layer that was attacked by pickling soluton is apparently eroded away. Etched electrolytically in oxalic acid, 400X.

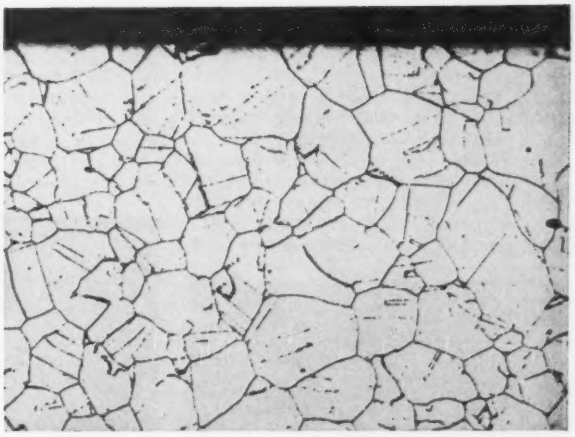


Figure 10—Microstructure of Type 304 stainless steel sensitized for four hours at 1250 F (not pickled) and exposed in loop for 89.2 hours. No corrosive attack is visible. Etched electrolytically in oxalic acid, 400X.

at appreciably higher rates than was as-received Type 304 or sensitized, non-pickled Type 304 in test-loop systems at a velocity of approximately 28 fps; however, when the layer of metal attacked by the pickling solution was removed by the action of the slurry, the attack diminished.

3. At higher velocities, somewhat over 28 fps, sensitized and pickled Type 304 stainless steel was continuously attacked at significantly higher rates than was as-received Type 304 or 347. This is believed to be due to the rough surface that a pickled specimen presents to the flowing slurry. The rough surface tends to form stronger eddies as the slurry flows

at higher velocities, and thus the erosion of the specimen is increased.

4. To minimize corrosion-erosion of sensitized Type 304 components in high-velocity slurry under loop operating conditions, pickling after sensitization and prior to test-loop exposure should be avoided. In practice it was found unnecessary to pickle loop components, since any heat-tint resulting from welding did not interfere with loop operation. After construction, loops usually were cleaned by being operated for short periods while containing a detergent solution. This procedure removed grease and other foreign material from the system.

5. As-welded Type 304 would not be expected to be susceptible to intergranular corrosion by the environment studied when the heat tint caused by welding is not removed by a pickling operation.

Acknowledgment

The Pennsylvania Advanced Reactor corrosion-study program was conducted by the Chemical Engineering Section of the Pennsylvania Advanced Reactor Project. This work was completed while the author was on loan from the U. S. Steel Applied Research Laboratory in Monroeville, Pennsylvania, to the Westinghouse Atomic Power Department in Pittsburgh, Pennsylvania. Loop operations were supervised by Mr. J. F. West, Jr.; metallographic work was done under the supervision of Mrs. D. J. Rahn and Mr. J. H. Powers; and helpful discussions were held with Mr. L. Marti-Balaguer.

The author wishes to thank the management of Pennsylvania Power and Light Company and of Westinghouse Electric Corporation for permission to publish these data.

References

1. W. E. Johnson, D. H. Fax, and S. C. Townsend. PAR Homogeneous Reactor. *Mechanical Engineering*, 79, No. 3, 242 (1957).
2. E. C. Bain, R. H. Aborn, and J. J. B. Rutherford. The Nature and Prevention of Intergranular Corrosion in Austenitic Stainless Steels. *Transactions, American Society for Steel Treating*, 21, 481 (1935).
3. H. H. Uhlig (Editor). Corrosion Handbook. John Wiley and Sons, Inc., 1948, pp. 161-164.
4. D. J. DePaul (Editor). Corrosion and Wear Handbook, U. S. Atomic Energy Commission, TID 7006, March 1957, pp. 225-28.

Any discussion of this article not published above will appear in June, 1961 issue.

Technical Papers on Corrosion Welcomed

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

Corrosion Studies of Aluminum In Chemical Process Operations*

By E. H. COOK, JR., R. L. HORST and W. W. BINGER

Abstract

Several developments are presented which describe the evolution of laboratory studies into commercial applications for aluminum alloys in the chemical and petroleum industries. Particular attention is given to the study of aluminum alloys for handling 83 percent ammonium nitrate solutions at elevated temperature. Based on laboratory results, operating procedures have been established for the storage and handling of 83 percent ammonium nitrate. The discussion also includes applications of aluminum in the production and handling of aliphatic acids, sour crude oil, amines, hydrogen peroxide, fuming nitric acid, liquids at cryogenic temperatures, and high purity water. While the preference for aluminum is often based on corrosion resistance, other properties that may be equally important include protection of product purity, light weight, and absence of catalytic action.

6.4.2, 8.8.1, 8.4.3

Introduction

PROPERLY CONCEIVED laboratory corrosion tests can duplicate many of the factors encountered in service and serve as excellent guides to the intelligent use of materials. Different tests are required for different applications or pieces of equipment. For example, heat exchanger tubing is evaluated under heat transfer conditions because simple immersion tests do not tell the full story.[1] However, for tank cars or storage tanks, a simple immersion test is a good guide to suitability in service. Immersion tests may be supplemented by actual storage tests in small welded containers simulating operating conditions as nearly as possible. Tests should be at service temperatures in welded containers having an area-to-volume ratio as close as is feasible to the area-to-volume ratio of the actual tank or drum.

Where field studies are conducted in existing operating equipment, the samples should be installed in duplicate to evaluate the effect of time on corrosion rate. At the end of such studies, samples can be examined in the laboratory for weight loss, depth of attack and chemical analysis of surface products.

By considering all the factors involved in a particular process, it has been possible to make reliable predictions of the behavior of aluminum alloys in many applications based on laboratory and field data.

Alloy Studies

Fundamental to the use of aluminum in the chemical process industries is knowledge of the characteristics of the various alloys. A typical alloy study can be illustrated by the recent work done on the aluminum-magnesium series.[2]

Before the advent of the aluminum-magnesium alloy series, aluminum tanks, tank cars and tank trailers were constructed using 3003 alloy welded with 1100 and 6061 welded with 4043. These alloys have been used for many years with a variety of chemicals at both ambient and elevated temperatures, and have provided a basis for present day applications of aluminum alloys for the handling and storage of chemical compounds and solutions.

As the size of storage tanks increases, there is an economic advantage in using stronger aluminum alloys. Both 6061 and the strain-hardenable aluminum-magnesium alloys have been used where higher strength is required than is available from commercially pure aluminum. Figure 1 shows the largest aluminum storage tank in the world. This tank, constructed with a 5052 sidewall and 3003 alloy roof and floor, has a 2⅓ million gallon capacity and is used for storing 83 percent ammonium nitrate at 180-190 F.

The characteristics making the aluminum-magnesium alloys ideal for tankage and tank car applications are ease of welding, good weld strength and excellent resistance to corrosion. Mechanical properties of these aluminum-magnesium alloys become impressive when considering the shell thickness normally specified for aluminum tank trailers. On the average, shell and head gauge increase for aluminum over steel is 44 percent. Increasing the aluminum thickness 44 percent over the steel thickness gives an added advantage of reducing the chance for serious misalignment and resultant high localized stress. In addition, the inert gas shielded welding processes used on aluminum produce smooth, sound, flux-free welds.

Not all compositions of aluminum-magnesium alloys are suitable for service at elevated temperatures, because of the effect of temperature on their metallurgical structure. In general, strain hardened aluminum-magnesium alloys containing 3.5 percent magnesium or over are not recommended for service at temperatures in excess of 150 F, because precipitation of the α (Al-Mg) phase can occur. This constituent is anodic to the aluminum-magnesium solid solution. Susceptibility to stress corrosion cracking is closely related to the extent of precipitation of the α (Al-Mg) phase at the grain boundaries.[2]

The factors promoting precipitation of the aluminum-magnesium constituent are high magnesium content, cold work and time and temperature of reheating. In the annealed temper for an alloy with a magnesium content of 6 percent or less, precipitation occurs only slowly, if at all, whereas the introduction of sufficient cold work into the higher magnesium alloys enables precipitation to occur at relatively rapid rates.

For service at elevated temperatures, either 5052 (2.5 percent Mg), or the new higher strength alloy, 5454 (2.75 percent Mg + 0.80 Mn) is recommended. These alloys have shown no harmful grain boundary precipitation after heating sheet and plate for periods up to two years at temperatures in the range of 200 F to 400 F. Corrosion tests and service experience on 5052 and 5454

★ Submitted for publication April 4, 1960. A paper presented at the 16th Annual Conference, National Association of Corrosion Engineers, Dallas, Texas, March 14-18, 1960. This paper also appears in slightly modified form in "Proceedings of Short Course on Process Industry Corrosion, Ohio State University" (Copyright 1960 by NACE).

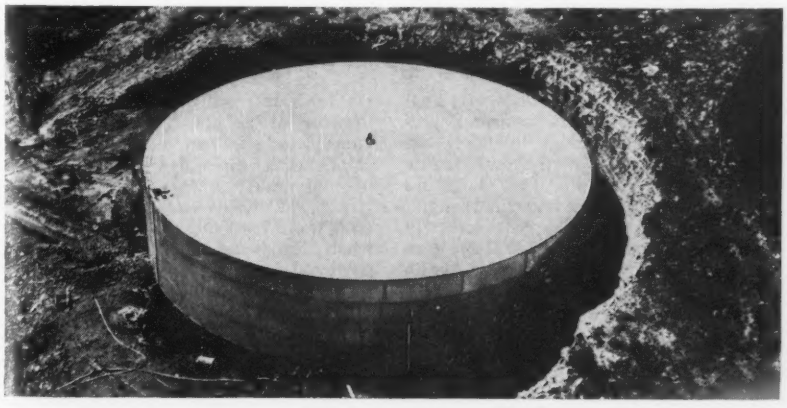


Figure 1—Ammonium nitrate storage tank built to store 83 percent ammonium nitrate fertilizer solution. The tank holds 2-1/3 million gallons and stands 26 ft. high and 128 ft. in diameter. The sidewalls are of Alcoa 5052 alloy plate with the bottom course thickness measuring 1⅞ inches. The floor and roof are of Alcoa 3003 alloy.

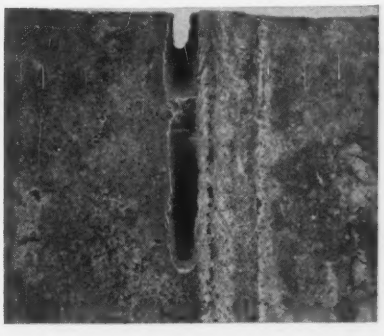


Figure 2—Type of attack observed on one 5052 bottom plate of an 83 percent ammonium nitrate storage tank. This attack was localized and occurred only in the heat affected zone adjacent to the 5052 weld.

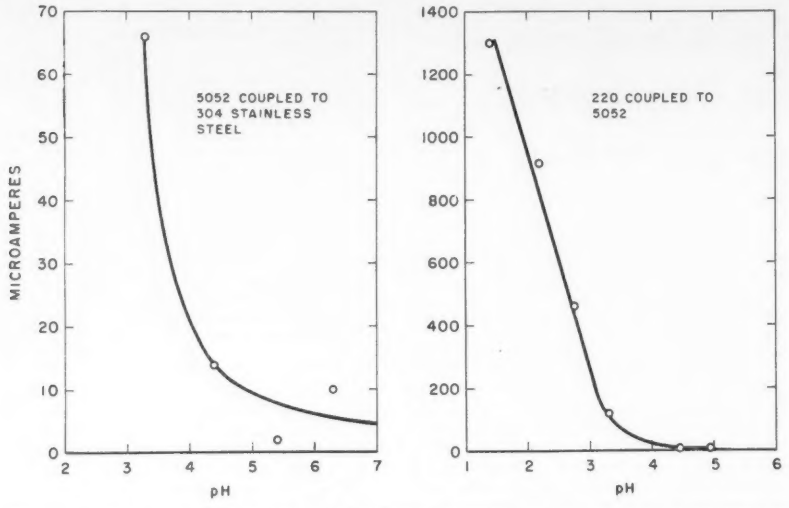


Figure 3—Effect of pH on galvanic currents in 83 percent ammonium nitrate. Note that the magnitude of the galvanic currents becomes negligible above a pH of 4.5-5.0. pH values were maintained with either HNO_3 or NH_3 as required.

Cook Horst Binger

E. H. COOK, JR., is research engineer in the chemical metallurgy division at the Alcoa Research Laboratories, New Kensington, Pa. His work is primarily in fundamental studies of corrosion mechanisms and development of aluminum alloys for the chemical industry. He is a member of NACE and has a PhD in chemistry from Pennsylvania State University.

W. W. BINGER, chief of the chemical metallurgy division of the Alcoa Research Laboratories, New Kensington, Pa., has been with Alcoa since 1943. His principal activity has been in development of aluminum alloys for chemical industry applications. He was the 1959 chairman of the NACE Northeast Region and has a BS in chemical engineering from the University of Wisconsin.

R. L. HORST, JR., is affiliated with the sales development division of the Aluminum Company of America, New Kensington, Pa. His work is on aluminum applications in the chemical and process industries. An NACE member and a graduate of Columbia University, he has published several articles on aluminum and cathodic protection by aluminum and magnesium anodes.

substantiate the excellent resistance of these alloys to corrosion and stress corrosion. One recent application of 5454 has been for the construction of hot asphalt tank trailers.

Aluminum Alloys for Ammonium Nitrate Storage Applications

Aluminum has been used for many years in the processing, handling and storage of ammonium nitrate explosives. The widespread use of aluminum accompanied rapid increase in ammonium nitrate production for fertilizers. Typical applications include equipment for blending, storage and handling of ammoniated ammonium nitrate, storage of 83 percent ammonium nitrate (Figure 1), prilling towers for solid ammonium nitrate, and tank cars for solutions.[3,4,5] At present over two thousand 6061 and 5052 tank cars are used in ammonium nitrate fertilizer service.

Generally, aluminum alloys are used for handling the hot concentrated ammonium nitrate solutions following the neutralizing step. They are used because it has been demonstrated that aluminum alloys are not attacked by ammonium nitrate containing a slight excess of ammonia. Aluminum alloys have become standard materials of construction in the storage and handling of this 83 percent ammonium nitrate product. The temperature of the product during storage has varied from 170 F to 212 F at different plant locations. As ammonium nitrate leaves the neutralizer at about 250 F it enters the storage tank where the temperature is maintained at about 180 F. Under these operating conditions, where an excess of ammonia is present, it has been established that alloys 1100, 3003, 5052, 5454, 6061 and 6063 (including welded joints) all have excellent resistance to corrosion.

In the past, occasional difficulties in ammonium nitrate service have arisen which have been traceable to two main causes: (1) acidic conditions, and (2) mercury contamination. It has been shown that attack by acidic ammonium nitrate solutions can be stopped by adjusting the product with ammonia to neutralize the free nitric acid. Mercury contamination has long been recognized as a corrosion hazard, particularly with non-ferrous metals.[6,7] Therefore, every effort should be made to avoid such contamination. Mercury-containing pH electrodes, thermometers, manometers, etc., if improperly handled, can be sources of mercury contamination.

Effect of pH

Adequate circulation of the product during storage will prevent the development of local acidic conditions and also provide a more uniform product. One particular 5052 alloy tank (designed for service at 180-190 F with 83 percent ammonium nitrate at a pH of 6.5-7) had a history of repeated failures adjacent to the 5052 weld beads on the bottom of the tank (Figure 2). An intensive investigation was undertaken to determine the cause of this unusual performance.

In the laboratory, attack on 5052 in the heat affected zone adjacent to 5052 weld beads could be reproduced in 83 percent ammonium nitrate by:

1. Galvanic coupling of the welded 5052 specimen to a cathodic metal such as stainless steel at pH values below 4.5.

2. Application of anodic current to induce corrosion.

3. Immersion of a welded specimen in 83 percent ammonium nitrate solution containing free nitric acid at pH values below 3.

In these studies the pH was measured in the 83 percent ammonium nitrate solution **at the operating temperature (180 F)**. Whenever a sample of the 83 percent ammonium nitrate is diluted with an equal volume of water and cooled to room temperature, the pH measured in this way is from 1 to 1.5 units higher than values measured directly in the hot 83 percent solution.

Under hot storage conditions excess ammonia is readily lost, resulting in a lowering of the pH. As pointed out previously, attack can occur on certain combinations of welded aluminum alloys in ammonium nitrate containing free nitric acid. This localized attack usually occurs on the bottom of storage tanks where, in the absence of adequate circulation, variations in acidity are likely to develop at the metal surface. Along the sidewalls there exists a natural circulation as well as a lower temperature which aids in maintaining a uniform and higher pH.

To further demonstrate the effect of pH, a test was initiated in which a series of 5052-stainless steel couples was exposed at 190 F to 83 percent ammonium

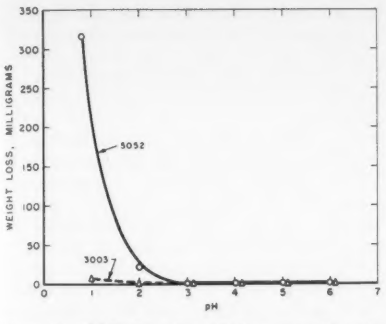


Figure 4—Weight loss after 17 days, at various pH values, of 3003 and 5052 sheet specimens, ½" x 3" x 0.064", in 83 percent ammonium nitrate solutions at 190 F.

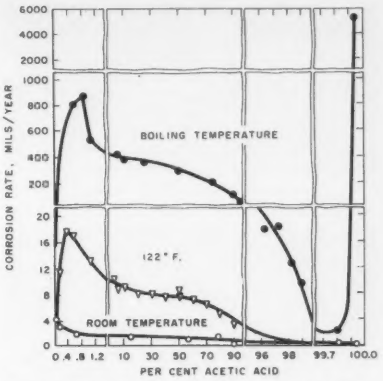


Figure 5—The effect of concentration and temperature on the corrosion rate of 1100-H14 aluminum alloy in acetic acid. Experience has shown that this curve can be applied generally to aluminum alloys.

Figure 6—Alloy 6061-T6 top rings and roof decks being installed on 10,000 barrel sour crude oil storage tank near Odessa, Texas. Aluminum is used here because of its excellent resistance to corrosion by sulfur compounds in the vapor space.

nitrate solution having the pH of the solution adjusted to 3, 4.5, 5 and 6. The purpose of the stainless steel was only to supply a sufficient cathodic area so that anodic areas were stimulated on the welded 5052. During a three week exposure period, the only aluminum specimen that exhibited any sign of corrosion was the specimen exposed to the solution maintained at a pH of 3. The corrosion was localized adjacent to the weld beads, and resembled the attack shown in Figure 2. Measurements of the galvanic current between the welded 5052 and the stainless steel indicated the magnitude of the galvanic current was dependent on the pH of the solution as illustrated in Figure 3 (left graph). Above a pH of 4.5 the magintude of the galvanic current was insignificant. Similar measurements between couples of 5052 and more anodic aluminum-magnesium alloys containing higher amounts of magnesium also indicated the magnitude of the galvanic current was dependent on the pH of the solution as illustrated in Figure 3 (right graph). Furthermore, it was demonstrated that the addition of ammonia at the lower pH's immediately stifled the galvanic current.

Laboratory tests demonstrated that ammonium nitrate at temperatures as high as 250 F was compatible with 5052, even when coupled to stainless steel, provided that sufficient ammonia was present to maintain the pH of the solution above 6. In these tests which were run for one month, a pressurized system was used so that ammonia would not be lost during the course of the test. At lower pH values, as was expected, localized attack was observed adjacent to the weld.

At pH values of 3 and below, tests with (unwelded) sheet specimens of 5052 alloy indicated this alloy to have a high overall corrosion rate in 83 per cent ammonium nitrate, whereas the corrosion rate of (unwelded) 3003 sheet was essentially nil. Weight losses of these alloys as a function of pH in 83 per cent ammonium nitrate are illustrated in Figure 4. It was not possible to produce localized attack on 3003 alloy welded with 1100 weld wire. These data indicate both welded and unwelded 3003 alloy to be more tolerant of acidic conditions in 83 per cent ammonium nitrate than either welded or unwelded 5052 alloy.

It was reasoned that once an acidic condition was established, corrosion could start and be self-perpetuated as long as the acidic condition exists. Furthermore, it was reasoned that as attack progresses, the solution surrounding the anodic area would become even more acidic, thereby further aggravating corrosion.

A special galvanic cell was devised in which a lap welded 5052 specimen (2" x ½" x ¼" with a ¾" weld overlay) was placed in a porous cup within a beaker of 83 per cent ammoniuum nitrate containing a 5052 panel (40 in²). Initially the welded specimen was driven externally as an anode to the 5052 cathode in the 83 per cent solution. The bulk solution of ammonium nitrate had a pH of 5.6. The pH of the anolyte decreased rapidly to 2.2. When the external current was removed, the specimen remained the anode and continued to corrode.

The above data emphasize that an acidic condition is necessary at the metal surface to promote corrosion of 5052 in 83 per cent ammonium nitrate. The acidic condition need only exist at localized areas as in the above case where the bulk solution of ammonium nitrate presumably contains an "excess" of ammonia.

Recommended Storage Practice

Recommendations for the handling and storage of 83 per cent ammonium nitrate in aluminum alloys are consistent with standard operating procedures to insure a uniform product. These are:

1. Maintain a minimum storage temperature to reduce the amount of ammonia required to produce a uniform quality product containing excess ammonia (pH 6 or above).

2. Provide adequate circulation to maintain a uniform temperature as well as to achieve a product of uniform quality.

If these recommendations concerning temperature, pH and adequate circulation of the solution are followed, 83 per cent ammonium nitrate solutions can be handled in any of the following aluminum alloys: 1100, 3003, 6061, 6063, 5050, 5052, 5454, and their recommended filler wires.

Aliphatic Acids and Anhydrides

For many years the compatibility of aluminum and organic acids has been recognized.[8] Chemicals such as acetic anhydride are carried in steel barges fitted with aluminum tanks. Since these vessels operate at a given draft, considerably more chemical may be carried in aluminum tanks than in tanks of other materials because of the lighter weight of aluminum. The use of aluminum prevents discoloration of the products and permits their use in the manufacture of textiles and films.

Previous studies[9] established that aluminum alloys are resistant to corrosion by 99.5 per cent acetic acid even up to the boiling point. However, when the water content is reduced to less than 0.2 per cent, severe non-uniform attack is encountered at temperatures above 50 C. The effect of temperature and concentration on the resistance to corrosion of 1100-H14 in acetic acid is shown in Figure 5. No appreciable differences in behavior of various aluminum alloys were noticed. The presence of acetic anhydride in the glacial acid does not effect the corrosion rate at temperatures below 50 C.

Propionic and butyric acid are analogous to acetic acid in their behavior toward aluminum alloys. In every case both commercial strength acid and anhydride were compatible with aluminum alloys at the boiling point. Mixtures of acetic acid—acetic anhydride caused rapid corrosion of aluminum at the boiling point while mixtures of butyric acid —butyric anhydride did not cause rapid corrosion unless the acid was dehydrated (less than 0.2 per cent water) prior to mixing with the anhydride.

The "water whiteness" of acetic acid is assured by the use of aluminum equipment. Aluminum storage tanks are employed to a considerable extent for the storage of glacial acetic acid, acetic anhydride and their mixtures. Some of these tanks have been in service for over 30 years. Aluminum alloy tank cars are also used for the transporting of these acids and anhydrides. In addition to tanks and tank cars, aluminum drums and pipe are used successfully to handle these chemicals.

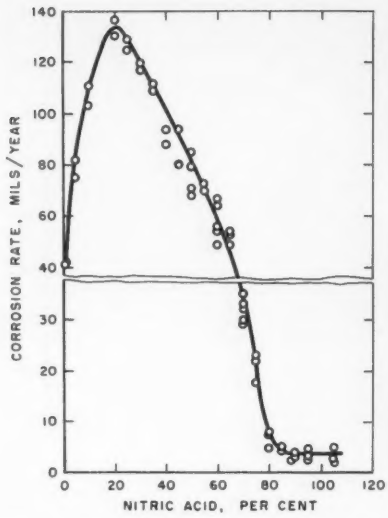


Figure 7—Effect of concentration of nitric acid solutions at room temperature on the corrosion rate of 1100-H14 alloy. Other aluminum alloys normally considered for use in chemical plant applications have the same degree of corrosion resistance to nitric acid solutions.

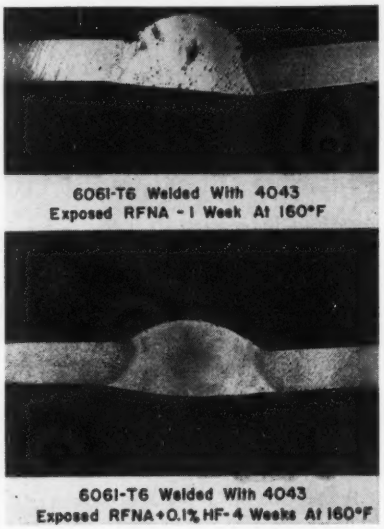


Figure 8—Addition of 0.1 percent HF to red fuming nitric acid inhibits knifeline attack on aluminum alloys at 160 F. With uninhibited acid, this attack is observed only above 122 F.

Alcohols

At room temperature, the short chain aliphatic alcohols are compatible with aluminum alloys. Aluminum alloys are used commercially for the handling of methyl, ethyl, propyl, butyl and higher alcohols. At higher temperatures an analogy exists between alcohols and short chain aliphatic acids.

Aluminum has a high corrosion resistance to commercial alcohols even at elevated temperatures, provided that a trace of moisture is present. However, at elevated temperatures anhydrous ethyl, propyl and butyl alcohols are corrosive towards aluminum alloys. This has not been observed in the case of methyl alcohol, possibly because of the difficulty involved in the removal of water from methyl alcohol. Aqueous alcohol solutions have only a slight effect on aluminum.

To insure purity and clarity of the product, aluminum equipment is used with alcohols in the production of antibiotics, perfumes, plastics and in the beverage industry.[10] Aluminum is also considered a standard material of construction for tanks and tank cars for the handling of higher alcohols such as glycerine, because aluminum does not cause yellowing of glycerine.

Sour Crude Oils

Aluminum roofs for sour crude oil storage tanks have been in service for more than 30 years in locations where steel roofs failed in less than five years.[11] Erection of aluminum top courses and roofs on two sour crude tanks is illustrated in Figure 6. Aluminum bubble caps have been in service for 10 to 15 years in cracking unit fractionating columns for sour crude oils at temperatures up to 625 F. Since aluminum alloys have an exceptionally high resistance to sulfur fumes and gaseous compounds of sulfur, these alloys are used for building materials and structural parts for plants in sulfur producing areas and in regions where the atmosphere is contaminated with sulfur or sulfur bearing compounds.

Amines

Aluminum alloys are successfully used to handle glycol-amine solutions for the removal of products such as hydrogen sulfide and carbon dioxide from natural gas. The amine process employs either an aqueous solution of an alkanolamine or a mixture of the amine plus diethyleneglycol and water. The amine is contacted with the gas to be treated and subsequently denuded of its acid gas content by heating to its boiling point. With such a cyclic operation the amine solution can be re-used continuously, and a treated gas of very high purity with respect to hydrogen sulfide and carbon dioxide is obtained.

Alkanolamine solutions containing 40 per cent or more glycol do not appear to be corrosive to aluminum.[12] In the presence of acid gases, these solutions are still non-corrosive to aluminum alloys, although they are corrosive to steel. Glycol-amine solutions are handled and recovered in treating plants using aluminum tubed lean-rich exchangers, solution coolers, acid gas coolers and reboilers. In addition, the top half of the regeneration towers has been constructed of aluminum and fitted with aluminum bubble caps and trays.

Aluminum specimens galvanically coupled to steel in glycol-amine solutions (80 per cent glycol plus 5 per cent water plus 15 per cent amine) in the presence of hydrogen sulfide and carbon dioxide, showed no attack on the aluminum although steel showed profuse pitting.[12]

Aqueous amine solutions themselves are said to be non-corrosive to steel regardless of temperature. However, in the presence of the acid gases, these amines can be severely corrosive to steel. In contrast, aqueous 15 per cent monoethanolamine (MEA) showed an appreciable corrosion rate on aluminum alloys in the absence of acid gases, but when hydrogen sulfide and carbon dioxide were present, the attack was reduced to insignificance.

Unpublished data from Alcoa Research Laboratories indicate the maximum corrosion rate on aluminum alloys occurs when the concentration of the aqueous MEA is 15 per cent. At room temperature, corrosion rates as high as 950 mpy were observed, whereas the presence of acid gases (5 gms/liter), hydrogen sulfide and/or carbon dioxide, reduce the attack to about 6 mpy. More concentrated solutions of MEA showed little or no attack of aluminum alloys; for example, above 97 per cent the corrosion rate was less than 0.2 mpy. Published results[12] indicate that galvanic coupling of 3003 to carbon steel in aqueous 15 per cent MEA actually depressed the attack on the aluminum.

Propellants

Hydrogen Peroxide

Aluminum is the only common metal which does not catalyze the decomposition of hydrogen peroxide. Because of this, H_2O_2 solutions are produced, piped, stored and shipped in aluminum. Commercial H_2O_2 solutions are shipped either as 35-50 per cent solutions or as 90-100 per cent solutions.

Peroxide producers and users prefer aluminum alloys with special controls on copper and manganese. The API Tank Code and ICC Specifications permit the use of these high purity versions of approved alloys.

Field erected tanks for handling 90 per cent H_2O_2 solutions are usually constructed of 1260, 5254 or 5652 alloy. Tank cars are usually constructed of 5254 or 5652 alloy welded with 5254 weld wire.

An initial "passivating" treatment of a new aluminum surface is universally recommended to improve its compatibility with the peroxide. In many cases, the passivating treatment includes degreasing followed by exposure to a chemical cleaning solution prescribed by the peroxide producer. The passivation treatment is required only for new equipment or for tank cars taken from other service.

Two iron removal solutions were developed at Alcoa Research Laboratories.[13, 14] This was done because the presence of iron contamination on the aluminum surface, picked up particularly during fabrication of equipment, will catalize decomposition of peroxide. The use of iron removal solutions produces aluminum surfaces with much less catalytic effect on the stability of 35 per cent hydrogen peroxide than did a surface that was merely degreased and acid treated. After 20 weeks, an untreated 5254 sample gave 90 per cent decomposition of 35 per cent peroxide solution compared to only 6 per cent decomposition for a blank. The treated 5254 sample also caused only about 6 per cent decomposition of the product. Using 1260 alloy for the same period of time, untreated surfaces caused 12 to 38 percent decomposition, whereas treated sur-

faces behaved in the same manner as the blank.

The presence of chloride contamination in hydrogen peroxide causes pitting of aluminum alloys. Since as little as 2.5 ppm chloride, in 35 per cent hydrogen peroxide, caused pitting on 1260 alloy after a seven day test, contamination by chloride should be prevented.

Fuming Nitric Acid

Extensive studies conducted at Alcoa Research Laboratories revealed that aluminum alloys were very resistant to corrosion by concentrated nitric acid solutions.[15] The effect of concentration on the corrosion rate is illustrated in Figure 7. Aluminum equipment is used in the manufacture and handling of nitric acid solutions over 82 per cent by weight, particularly the fuming varieties. Equipment includes cooling coils, condensers, piping, hoods, storage tanks, tank cars and drums. The presence of lower oxides of nitrogen in fuming nitric acid does not significantly effect the resistance to corrosion.[16]

All aluminum alloys, welded and unwelded, have good resistance to uninhibited fuming nitric acids (red and white) up to 122 F. Above this temperature, most aluminum alloys exhibit knifeline attack adjacent to the welds in uninhibited acid. Above 122 F the depth of knifeline attack increases markedly with temperature. One exception was in the case of a fusion welded 1160 alloy in which no knifeline attack was observed even at temperatures as high as 160 F. In inhibited fuming nitric acid containing at least 0.1 per cent HF, no knifeline attack was observed for any commercial aluminum alloy or weldment even at 160 F.

Figure 8 shows a photomicrograph of knifeline attack on welded 6061-T6 after one week exposure to uninhibited red fuming nitric acid at 160 F, and the absence of knifeline attack after a 4 week exposure to inhibited red fuming nitric acid at the same temperature.

Steam and High Purity Water

The presence of dissolved oxygen and carbon dioxide make steam and steam condensate corrosive to some materials of construction. Aluminum is well suited for handling steam or condensate containing carbon dioxide and oxygen. Twelve year service data on aluminum piping handling water at 160 F indicated aluminum to be essentially unaffected, whereas during the same period of time galvanized pipe suffered severe tuberculation.[17] Figure 9 shows a flow diagram of a steam power plant and illustrates where aluminum alloys can be used.

Aluminum storage tanks, distribution lines, fittings and valves, are highly satisfactory for handling distilled and deionized water because they result in minimum contamination of the water being handled. Results with deionized water in one all aluminum system indicated that after an initial conditioning period of less than 10 days, aluminum pick-up was less than 0.01 ppm. In one chemical plant, a 3,000 gallon storage tank constructed of 3003 alloy handling deionized water showed a total aluminum pick-up of only 0.019 ppm after 3-½ years service.

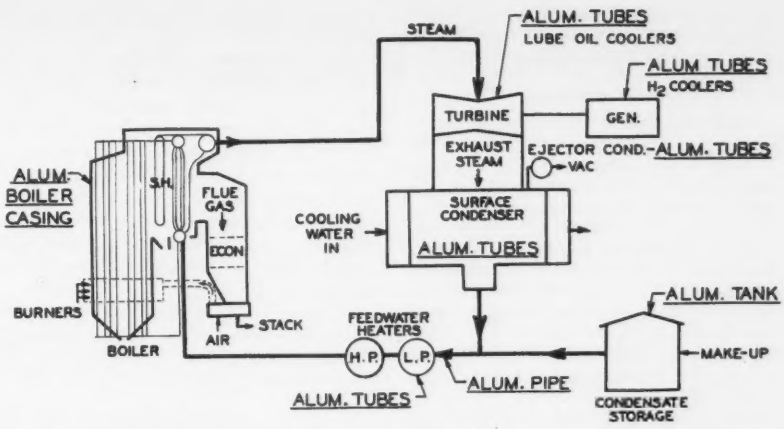


Figure 9—Systematic diagram of steam power circuit in typical high pressure power plant. Aluminum applications are being used in increasing amounts in steam power plants to reduce costs and to maintain better quality condensate.

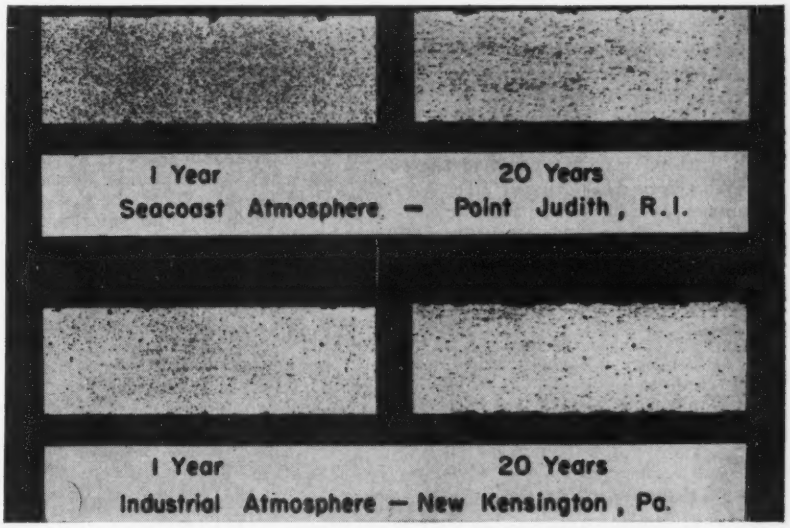


Figure 10—Photomicrographs of cross sections of 0.064 inch thick sheets of alloy 3003 after exposures indicated. Note that corrosion develops at isolated sites, slowly spreads to new sites, but is not appreciably deeper after 20 years than after one year. This pattern is typical for other corrosion-resistant aluminum alloys.

Most commerical aluminum alloys are not recommended for handling high purity water above 480 F.[18] At 514 F, the weight loss of 3003 increased sharply after 72 hours of exposure. At a temperature of 597 F, a 3003 specimen was completely disintegrated in less than 24 hours. For atomic energy applications where these higher temperatures are encountered, Alcoa has made available alloys X8001, X8002, and X8003. These alloys have good corrosion resistance to high purity water at temperatures up to 680 F.[19]

Cryogenic Applications

While aluminum is completely resistant to liquid air, oxygen, nitrogen, etc., and forms no explosive acetylides, the most dramatic characteristic of aluminum alloys which suits them for cryogenic equipment is their freedom from embrittlement at low temperatures. All mechanical properties of aluminum alloys, including strength, elongation, impact resistance and ductility, improve as the working temperature is lowered. For example, at -320 F the tensile and yield strengths of most aluminum alloys are about 40 per cent and 20 per cent higher, respectively, than at room temperatures.[20]

Since there is not a sufficient domestic demand for all the natural gas that is released during drilling operations, balsa-insulated aluminum tanks are used for the shipping of liquid methane overseas.[21] One ocean going vessel, *The Methane Pioneer,* utilizes five aluminum cargo tanks to carry liquid methane at -258 F. In addition to the tanks used for shipping, aluminum storage tanks are also utilized as part of the dockside facilities for handling the liquid methane. Other cryogenic applications of alumi-

num alloys include use with pure oxygen, nitrogen, hydrogen, argon, helium, and anhydrous ammonia and propane.

Weathering

Outdoor exposure tests for periods as long as 20 years, show aluminum alloys to have a high resistance to atmospheric weathering.[22] This is attributable to the "self-stopping" nature of the attack of aluminum alloys. This self-stopping attack is illustrated by the photomicrographs in Figure 10. After an initial exposure period of one or two years, the maximum rate of penetration, or corrosion, is less than 0.2 mpy for sea coast atmospheres and less than 0.1 mpy for atmospheric weathering normally encountered.

Aluminum alloys also exhibit a high resistance to corrosion where the atmosphere is contaminated by fumes and chemicals that promote the corrosion of many metals and alloys.[23] Plants having atmospheres containing combinations of hydrogen sulfide, carbon dioxide, sulfur dioxide, hydrogen chloride, moisture and dirt, have special reasons for preferring aluminum architectural items.

Conclusion

An attempt has been made to show how laboratory data, coupled to service experience or field tests, have made it possible to make reliable predictions as to the behavior of aluminum alloys in the chemical process industries. Aluminum alloys are being used for the storage and handling of ammonium nitrate, aliphatic acids, alcohols, sour crude oils, amines, hydrogen peroxide, fuming nitric acid, high purity water and liquid gases at cryogenic temperatures. Not only do aluminum alloys have excellent corrosion resistance to these chemicals, but they also have excellent resistance to atmospheric weathering. Other uses of aluminum in the chemical industry are beyond the scope of this paper and should best be discussed in subsequent publications.

The best use of aluminum alloys in the chemical industries can be obtained by taking advantage of the information and experience that is readily available.

DISCUSSION

Question by Louis J. Zadra, East Chicago, Indiana:

Is aluminum suitable for transporting vinegars containing up to 10 per cent acetic acid and other organic acids?

Reply by E. H. Cook Jr., R. L. Horst and W. W. Binger:

Laboratory tests indicate that when vinegar is relatively pure, no pitting attack of the aluminum specimens occurred, but when the vinegar contained heavy metal and chlorides, localized attack on the aluminum specimens developed. Since the action on aluminum varies with the vinegar, a sample should be tested prior to use with aluminum. The presence of other organic acids in the vinegar would not be expected to increase the corrosion rate under ambient conditions.

References

1. W. W. Binger and H. W. Fritts. *Corrosion*, 10, 425 (1954).
2. E. H. Dix, Jr., W. A. Anderson and M. Byron Shumaker. *Corrosion*, 15, 55t (1959) Feb.
3. W. H. Shearon, Jr. and W. B. Dunwoody. *Industrial and Engineering Chemistry*, 45, 496 (1953).
4. H. N. Hockensmith. *Welding Journal*, 29, 729 (1950).
5. A. S. Hester, J. J. Dorsey, Jr. and J. T. Kaufman. *Industrial and Engineering Chemistry*, 46, 622 (1954).
6. M. H. Brown, W. W. Binger and R. H. Brown. *Corrosion*, 8, 155 (1952).
7. R. C. Plumb, M. H. Brown and J. E. Lewis. *Corrosion*, 11, 277t (1956).
8. R. Seligman and P. Williams. *Journal Society of Chem. Ind.*, 35, 88 (1951); *ibid.*, 36, 409 (1917).
9. A. B. McKee and W. W. Binger. *Corrosion*, 13, 786t (1957) Dec.
10. J. D. Minford and T. S. Humphries. *Ind. and Eng. Chem.*, 48, 1975 (1956).
11. G. W. Alexander. *Petr. Ref.*, 26, 795 (1947).
12. F. C. Riesenfield and C. L. Blohm. *Petroleum Refiner*, 29, 141 (1950).
13. M. H. Brown. U. S. Patent 2901334 (August 25, 1959—Filed Nov. 3, 1958).
14. M. H. Brown. U. S. Patent 2901344 (August 25, 1959—Filed Nov. 3, 1958).
15. W. W. Binger. *Corrosion*, 8, 1 (1952).
16. M. G. Fontana. *Ind. & Eng. Chem.*, 45, 93A (1953).
17. C. J. Zetler. *Plant Engineering*, 10, 85 (1956).
18. W. W. Binger and C. M. Marstiller. *Corrosion*, 13, 591t (1957) Sep.
19. M. H. Brown, W. W. Binger and R. H. Brown. Aluminum Alloys For Handling High Temperature Water. High Purity Water Book, Publication 60-13, NACE, Houston, (1960) Oct.
20. K. O. Bogardus, G. W. Stickley and F. M. Howell. A Review of Information on the Mechanical Properties of Aluminum Alloys at Low Temperatures. NACA-TN 2082, May, 1950; F. M. Howell. Low Temperature Properties and Application of Aluminum Alloys. Conference on Materials and Design for Low Temperature Service, Fort Belvoir, May, 1952.
21. *Marine Engineering Log*, 64, 53 (1959) Apr.
22. C. J. Walton, D. O. Sprowls and J. A. Nock, Jr. *Corrosion*, 9, 345 (1953).
23. W. W. Binger, R. H. Wagner and R. H. Brown. *Corrosion*, 9, 440 (1953).

Any discussion of this article not published above will appear in June, 1961 issue.

NACE Guide for Preparation of Articles for Publication

Persons interested in submitting articles on corrosion for publication in CORROSION can obtain upon request a copy of the "NACE Guide for Preparation of Papers." Write to CORROSION, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

Effect of Sodium Exposure On the Mechanical Properties of Zirconium*

By J. C. BOKROS*

Abstract

It was found that surface oxide which developed on zirconium in impure sodium significantly lowered the fatigue life at elevated temperatures. Hydrogen absorption, on the other hand, had little effect on the fatigue life at elevated temperatures but lowered the fatigue life at room temperature. Also, critical recrystallization which occurred above 950 F in zirconium (a phenomenon unrelated to the presence of sodium) reduced the fatigue life at elevated as well as low temperatures.

The effects attributable to sodium (i.e., the formation of surface oxide and absorption of reasonable amounts of hydrogen), did not significantly alter the tensile properties of zirconium at high temperatures. 6.3.20, 4.7, 3.5.8, 3.2.3

Introduction

ZIRCONIUM is an important material for thermalnuclear reactors because of its low-neutron absorption cross section and desirable physical and mechanical properties. However, because it is a reactive metal, contamination during high-temperature service can result in a deterioration of its properties. The effects of prolonged exposure to high-temperature sodium and the effects of contaminants originating from the exposure on the mechanical properties of zirconium were investigated.

Materials

The zirconium used was hafnium-free double arc-melted sponge obtained from the Bureau of Mines. The ingots were forged and hot-reduced to 0.08 inch to 0.10 inch sheet, and subsequently cold-reduced to 0.035-inch sheet with intermediate and final anneals at 1200 F for 15 minutes. The resulting sheets had the following typical composition:**

Element	Ppm by Weight
Fe	400
Si	400
Cu	2
Cr	500
O	1000 to 1200
H	25 to 50
N	40 to 120

Experimental

The exposures to sodium were conducted in dynamic loops with a linear sodium velocity in the sample chambers of about 0.03 ft/sec. The oxygen concentration of the sodium was controlled by means of either a cold trap or hot trap. The cold trap utilized the decreasing solubility of Na_2O with temperature to control the oxygen concentration in the sodium. An extension of the loop was controlled at a relatively low temperature which maintained the oxygen level at the solubility limit corresponding to the cold trap temperature. The hot trap utilized the high affinity of a zirconium-titanium alloy for oxygen at elevated temperatures to scavenge the oxygen from the sodium and maintain a low concentration.

Zirconium sheath material, as used in the Sodium Reactor Experiment, sustains its maximum flexural load during a reactor power-level change or scram. For this reason, a reverse-bend fatigue test was chosen to evaluate the environmental effects of sodium on the properties of zirconium.

The elevated temperature fatigue apparatus is shown in Figure 1. Experimental data were obtained at three temperatures: room temperature tests were performed in air, 510 F tests were performed in purified argon, and 985 F tests were performed in vacuum. Cantilever type specimens 0.030 to 0.031-inch thick and 0.125-inch wide with less than 0.001-inch taper in a one-inch gauge length were used. Prior to exposure to sodium the specimen surfaces were finished on 600-grit metallographic paper with the scratches parallel to the neutral axis.

Since the maximum stresses in sheathing material of this type are often beyond the yield point of zirconium, deflections were employed which would produce yielding in the outer fibers of the test specimens. Fatigue cycling speeds were chosen as low as possible yet high enough to result in failure in reasonable times. At room temperature and 510 F, 150 cpm was used; at 985 F, 56 cpm was used.

The tensile properties of zirconium exposed to sodium were also determined. Small tensile specimens with a rectangular cross section of 0.125 x 0.035-inch and a 0.5-inch gauge length were machined from zirconium corrosion tabs previously exposed in the dynamic sodium loops. These specimens were tested in argon at 500 and 985 F in an Instron tensile testing machine at a crosshead speed of 0.02-inch/min.

Results

Effect Of Exposure To Sodium On Fatigue

A number of specimens were exposed to sodium in the dynamic loops and subsequently fatigue tested. These specimens were found to be affected by the exposure in a number of ways. Oxygen was gettered by the zirconium and formed a tightly adherent surface oxide; a subsurface layer of alpha zirconium containing oxygen in solid solution formed beneath the surface oxide. Hydrogen was absorbed, homogenized rapidly, and after slow cooling from the exposure temperature, occurred in the zirconium as a precipitate of zirconium hydride. Regions of the zirconium which had been strained slightly became very coarse-grained due to critical recrystallization.[1] The magnitude of each of the above was dependent on the temperature and duration of exposure and the oxygen and hydrogen concentrations in the sodium. The exposure data and fatigue results are tabulated in Table 1. The fatigue life varied considerably among sodium-exposed specimens, each variation being peculiar to the time and temperature of each exposure and the contamination of the zirconium during the exposure.

A series of typical photomicrographs of zirconium after exposure in sodium

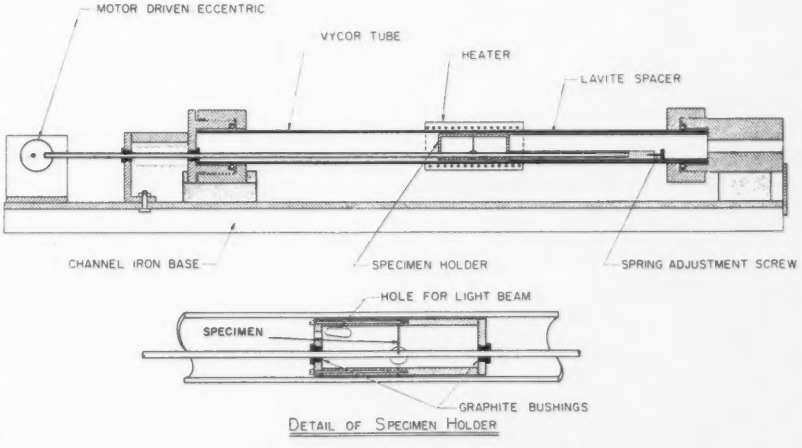


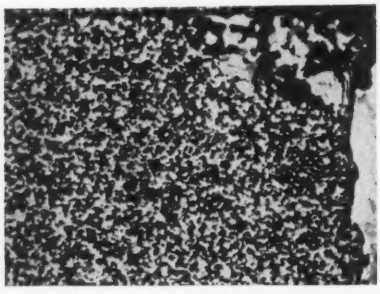
Figure 1—Fatigue testing apparatus.

★ Submitted for publication August 31, 1959.

* Research Staff, John Jay Hopkins Laboratory, General Atomic Division, General Dynamics Corp., San Diego, Calif.

** This is the same material used in the sodium reactor experiment, built and operated for the USAEC by Atomics International, Division of North American Aviation, Inc.

Bright Field, 55X



Polarized Light, 55X

Figure 2—Fatigue failure of specimen exposed 158 hours at 1000 F. Specimen gained 0.24 mg/sq cm plus 250 ppm hydrogen. Note the group of large grains in the photomicrograph taken with polarized light. The photo taken with bright field shows the hydride precipitate.

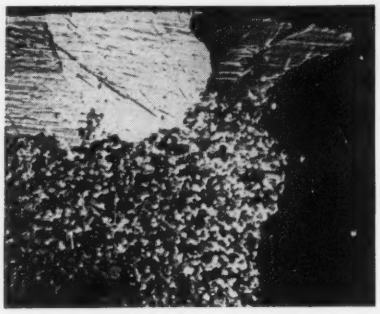


Figure 3—Fatigue failure specimen exposed 483 hours at 1100 F. Specimen gained 0.60 mg/sq cm plus 290 ppm hydrogen. Note large grains on the surface of the specimen. Approximately 55X.

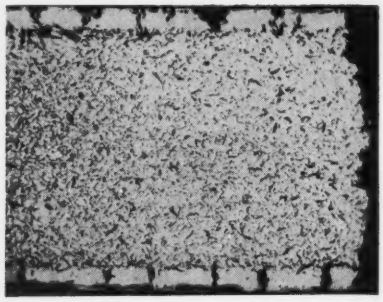


Figure 4—Fatigue failure of specimen exposed 504 hours at 1100 F. Specimen gained 0.53 mg/sq cm plus 505 ppm hydrogen. Note the white oxygen-rich layer on the surface which cracked severely during testing. Approximately 55X.

are shown in Figures 2, 3 and 4. In some cases the exposure temperatures were low, or the times sufficiently short, that grain growth was not observed and only contamination by hydrogen and oxygen resulted (specimens k-1 and k-2 in Table 1). Samples k-5 and k-6 were exposed to sodium whose oxygen level was so low that observable surface oxide did not form; however, some grain coarsening occurred and considerable amounts of hydrogen were absorbed.

Figure 2 shows a group of large zirconium grains formed during exposure. This group of large grains was located near the point of maximum stress in the fatigue specimen and caused a premature fatigue failure at 510 F. Sample k-4 was exposed at 1100 F for 483 hours in sodium having about 10 ppm oxygen. This exposure resulted in the formation of surface oxide, a layer of oxygen in solid solution, considerable hydrogen absorption, and critical recrystallization. The fatigue fracture of this specimen is shown in Figure 3. A photomicrograph of specimen K-7, shown in Figure 4 shows numerous cracks at the surface in the brittle oxygen-rich layer. In order to determine the individual effects of the sodium exposures, (i.e., the effects of critical recrystallization, surface oxide, and hydrogen absorption on the fatigue properties of zirconium) the experiments described below were performed.

Effects of Surface Oxide on the Fatigue Life of Zirconium. Exposure of zirconium to sodium containing 10 ppm oxygen produces a tightly adherent black-oxide surface film. In order to determine the effect of the surface oxide alone (i.e., without the interfering influence of hydrogen or grain size), fatigue specimens were prepared with surfaces oxidized up to a maximum of 1.62 mg/sq cm by oxidizing in oxygen.

The fatigue life as a function of surface oxide was obtained at room temperature, at 510 F and at 985 F, using a deflection of 0.10-in. and rates as given above (see Figure 5). Without exception, the presence of surface oxide on zirconium lowered its fatigue life significantly. The decrease in fatigue life occurred with the addition of the first 0.50 mg/sq cm; further oxidation resulted in no further loss in fatigue life.

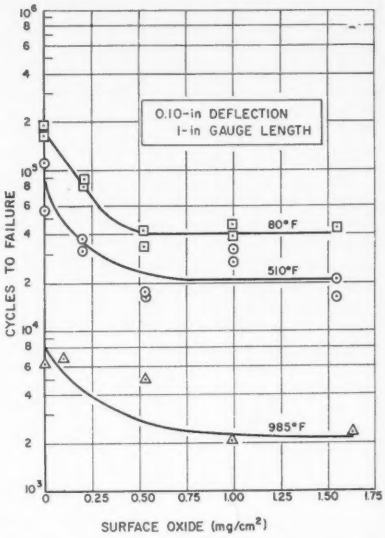


Figure 5—Effect of surface oxide on the fatigue life of zirconium.

Effect of Hydrogen on the Fatigue Life of Zirconium. A series of fatigue

TABLE 1—Fatigue Life of Zirconium Exposed in Sodium

Sample Number	Loop Number*	Exposure Temp. (°F)	Exposure Time (hr)	Oxygen (ppm in Sodium)	Hydrogen in Zirconium (ppm by Wt.)	Surface Oxide (mg/cm²)	Grain Size After Exposure (mm diameter)	Fatigue Cycles to Failure (0.13 in. Deflection 985 F)	Fatigue Cycles to Failure (0.10 in. Deflection 510 F)	Knoop Hardness No.
Unexposed	.....	....	....	.	25	....	0.015	2850–3400	58000–106000	153
k-1	1	760	706	65	49	0.14	0.015	1800	53000	158
k-2	3	1100	65	10	202	0.28	0.1, surface 0.015, interior	1750	24000	158
1	Can Head Flexure Test	960–980	590	..	35	0.65	0.015	1775	.....	154
k-4	3	1100	483	10	288	0.60	0.25	1550	16000	158
k-3	3	1100	299	10	294	0.47	0.25, one surface	1075	23000	152
k-7	3	1100	504	20	505	0.53	0.015, center 0.20, surface (spotty)	700	19000	156
k-5	2	1000	504	10	242	0.18	0.015	2550	67000	160
k-6	2	1000	158	10	251	0.24	0.015	2900	40000	163
2	Can Head Flexure Test	960	1200	..	162	0.40	0.015	1350	34000	153
3	Can Head Flexure Test	960	1200	..	169	0.46	0.015	1000	27000	153

* Loop Number 1—Cold trapped dynamic (150 pounds sodium).
Loop Number 2—Hot trapped dynamic (100 pounds sodium).
Loop Number 3—Cold trapped static pot (50 pounds sodium).

specimens was prepared which contained up to a maximum of 850 ppm of hydrogen by weight. At room temperature, using 0.10-inch deflection and 150 cpm, the presence of about 850 ppm hydrogen in a slowly cooled specimen decreased the fatigue life to one-third that of the untreated metal (Figure 6). At 510 F, using the same speed and deflection, the addition of up to 850 ppm of hydrogen to fine-grain zirconium had little effect on the fatigue life (see Figure 7). The same was true at 985 F (Figure 6) with a 0.13-inch deflection and at 56 cpm.

Since many failures in Heliarc-welded zirconium have been observed to occur in the heat affected zone, a number of specimens containing a weld were fatigue tested with the heat affected zone placed at the point of maximum fiber stress. Unexposed welds and welds with 630-ppm hydrogen were tested at room temperature, at 510 F and at 985 F. Results are plotted on Figures 6, 7 and 8. The results of these tests were the same as for the fine-grained material, (i.e., the added hydrogen had no effect on the fatigue life at 510 and 985 F).

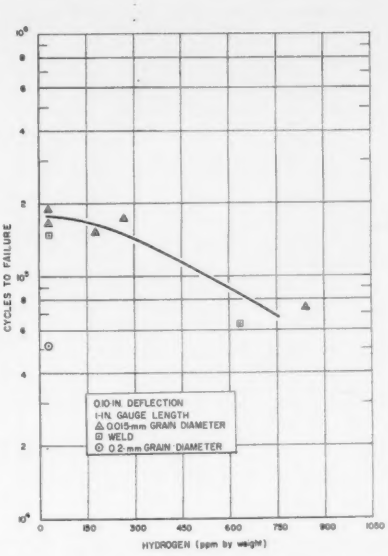


Figure 6—Effect of hydrogen on the room temperature fatigue life of zirconium.

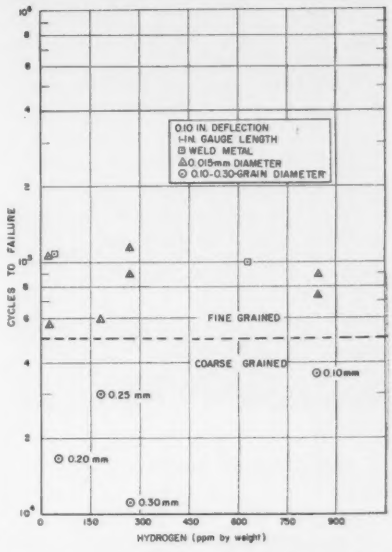


Figure 7—Effect of hydrogen and grain size on the fatigue life of zirconium at 510 F.

Effect of Grain Size on the Fatigue Life of Zirconium. Extended operating periods at temperatures above 950 F resulted in critical recrystallization of zirconium which had been plastically strained a small amount.[1] Consequently, a series of specimens was annealed for 170 hours in vacuum at 1300 F which resulted in grain sizes ranging from 0.1 mm to 0.3 mm; the original grains averaged 0.015 mm in diameter. These samples were fatigue tested in the same manner as duplicate samples with the same hydrogen contents but a fine grain size. The results at room temperature, at 510 and at 985 F are plotted in Figures 6, 7 and 8, respectively. In each case, the fatigue life was shortened by an increase in grain size. The scatter in some of the data is to be expected, since the hexagonal close-packed crystal structure of zirconium is anisotropic and the large grains individually exert a relatively large influence on the properties of each specimen. There was no effect of the varying hydrogen contents on the fatigue life of these specimens.

Effect of Exposure To Sodium On Tensile Properties

Tensile specimens cut from corrosion tabs previously exposed to sodium in the dynamic loops were tested at 510 F and 985 F. These specimens exhibited various combinations of surface oxide, hydrogen contamination, and recrystallization. The results from these specimens after exposure to sodium are summarized in Tables 2 and 3. Surface oxide, hydrogen, and grain size had little effect on the tensile properties. The reduction in strength observed was due to annealing.

Discussion

A significant decrease in fatigue life attributable to the formation of cracks in the surface oxide was observed with the addition of the first 0.5 mg/sq cm of

TABLE 2—500 F Tensile Tests of Zirconium Exposed in Dynamic Sodium (0.02 Inch Per Minute Strain Rate)

Loop No.*	Temp. (°F)	Time (hr)	Weight Gain mg/cm²	Hydrogen (ppm)	Ultimate (psi)	Yield Strength (psi)	Percent Elongation	Grain Size (mm)
As rec'd	....	....	....	25–30	30900	26000	38	0.015
As rec'd	....	....	....	25–30	31000	27000	27	0.015
3	1065	140	0.43	480	27400	21200	34	0.1–0.015, Spotty
3	1100	64	0.43	173	27000	20800	38	0.1–0.015, Spotty
3	850	130	0.11	94	28700	23200	43	0.015
2	1000	225	0.18	240	28800	21800	31	0.015–0.1, Spotty
1	850	570	0.20	90	26800	22300	43	0.015
1	850	570	0.20	90	27700	22100	41	0.015
1	925	62	0.11	68	27500	22300	28	0.015
1	1000	51	0.10	84	28800	19400	48	0.015
Anneal in vacuum 310 hr. 980 F	980	310	0.00	25	28000	23700	43	0.015

* Loop Number 1—Cold trapped dynamic (150 pounds sodium).
Loop Number 2—Hot trapped dynamic (100 pounds sodium).
Loop Number 3—Cold trapped static pot (50 pounds sodium).

TABLE 3—985 F Tensile Tests of Zirconium Exposed in Dynamic Sodium (0.02 Inch Per Minute Strain Rate)

Loop No.*	Temp. (°F)	Time (hr)	Weight Gain mg/cm²	Hydrogen (ppm)	Ultimate (psi)	Yield Strength (psi)	Percent Elongation	Grain Size (mm)
As rec'd	....	....	....	25	13200	11600	70	0.015
3	1100	147	0.376	318	10100	9700	68	0.13, Surface
3	1100	210	0.685	290	10700	9650	78	0.25, Surface 0.015, center
3	1100	299	0.703	304	9880	7730	58	0.20
3	990	215	0.450	225	10900	9130	90	0.015
2	1000	225	0.127	440	10300	9600	81	0.015
1	850	507	0.198	79.3	11400	9100	87	0.015
Anneal in vacuum 310 hr. 980 F	980	310	0.00	25	9650	8500	82	0.015

* Loop Number 1—Cold trapped dynamic (150 pounds sodium).
Loop Number 2—Hot trapped dynamic (100 pounds sodium).
Loop Number 3—Cold trapped static pot (50 pounds sodium).

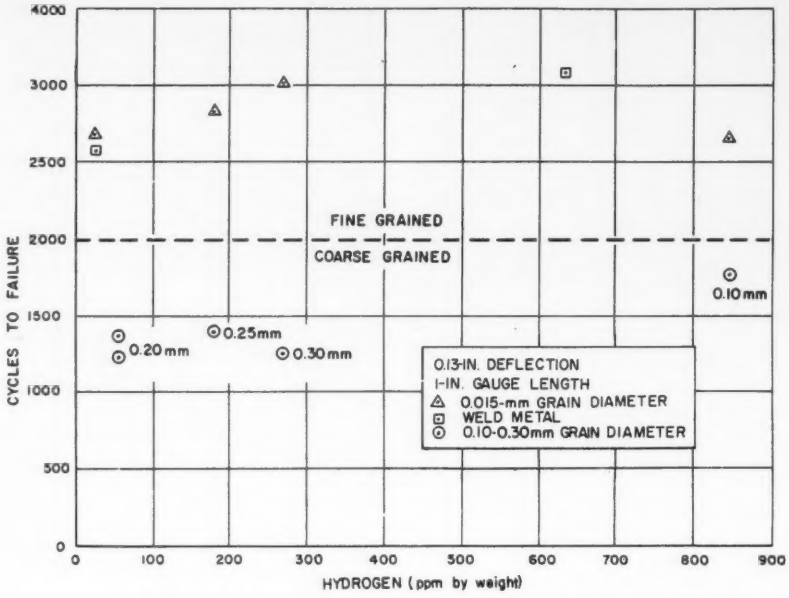


Figure 8—Effect of hydrogen and grain size on the fatigue life of zirconium at 985 F.

surface oxide. Further oxidation had little effect on the fatigue properties. Specimens with 1.6 mg/sq cm surface oxide tested for 30 percent and 70 percent of their expected fatigue life at 510 F were examined metallographically and revealed that cracks developed in the tightly adherent surface oxide before 30 percent of the expected life had elapsed. These cracks propagated into the metal, and resulted in failure (see Figure 9).

The lack of an effect of hydrogen on the fatigue life at 510 F and 985 F was due, at least in part, to the solution of some of the hydride. At 985 F the solubility is about 600 ppm and an extrapolation of the solubility curve to 510 F places the solubility at about 50 ppm by weight.

The reduction of the fatigue life of specimens with coarse grain structures was considerable at all test temperatures. Metallographic examination of these failures revealed that the fracture usually occurred along grain boundaries or along a preferred crystallographic plane. In coarse grained material, cracks formed at the surface and traveled a relatively large distance before being interrupted by another grain or grain boundary. For the specimens tested, this distance was as much as one-third the thickness of the specimen. As a result of this easy crack propagation in coarse grained material, the fatigue life was lowered.

Combinations of the effects discussed above appeared in the fatigue specimens exposed to sodium. Specimens k-5 and k-6, which were exposed in the hot-trapped dynamic loop, (1) picked up virtually no surface oxide, (2) absorbed about 250 ppm of hydrogen, and (3) experienced only a small amount of grain growth. These specimens exhibited fatigue lives near those of unexposed zirconium. The premature failure of k-6 at 510 F was due to a localized region of coarse grains (Figure 2) which was near the point of maximum fiber stress in the fatigue specimen. The exposure of samples k-1, 1, 2, and 3, was at a low enough temperature and short enough time to result only in the formation of surface oxide. The exposure of specimens k-4, k-3, and k-7 resulted in critical recrystallization, the development of surface oxide and a layer of oxygen-rich alpha solid solution, and the absorption of considerable amounts of hydrogen.

Figure 4 shows the 0.05 mm layer of oxygen-rich alpha-zirconium on specimen k-7; numerous cracks developed in this solution zone. This layer, in addition to the surface oxide, was undoubtedly responsible for the very low fatigue life of this specimen. All three of these samples had several regions of critically recrystallized material. The failure of specimen k-4 (Figure 3) is typical of coarse-grained material and illustrates the cracks that occurred in the large grains at the surface.

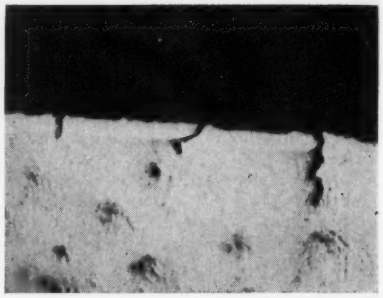


Figure 9—Surface cracks in the surface oxide of a fatigue specimen tested at 510 F. Approximately 55X.

In contrast to the fatigue data, the tensile data presented in Tables 2 and 3 reveal no severe reduction due to exposure to sodium. The only effect observed was a decrease in strength due to annealing. The formation of surface oxide, the absorption of hydrogen, and critical recrystallization had little effect on the strength and ductility at the strain rates and temperatures used. An increased grain size decreased the ductility at 985 F; however, this material still exhibited 50 percent elongation.

Conclusions

For the conditions of the fatigue tests employed at 510 and 985 F, hydrogen had little effect on the fatigue life of zirconium. At room temperature, hydrogen decreased the fatigue life.

Surface oxide up to 0.5 mg/sq cm lowered the fatigue life at all test temperatures. Above 0.5 mg/sq cm there was no significant further effect. Surface oxide acted as a crack initiator.

Increasing the grain size from 0.015 mm to 0.1 to 0.3 mm decreased the fatigue life at all test temperatures.

The formation of surface oxide to 0.6 mg/sq cm and the absorption of up to 450 ppm hydrogen during exposure to sodium had little effect on the tensile properties of zirconium at 510 and 985 F. Grain growth had little effect on the tensile properties of zirconium at 510 F but reduced the ductility at 985 F.

Acknowledgment

The author wishes to acknowledge the helpful discussions with Dr. R. L. Carter, and the sodium exposures carried out by R. B. Hinze, Dr. R. L. McKisson, and Dr. R. L. Eichelberger. Many of the mechanical tests were carried out by M. D. Wilcox.

Reference

1. J. C. Bokros, Critical Recrystallization of Zirconium. *Trans. AIME*, 218, (1960) April.

Any discussion of this article not published above will appear in June, 1961 issue.

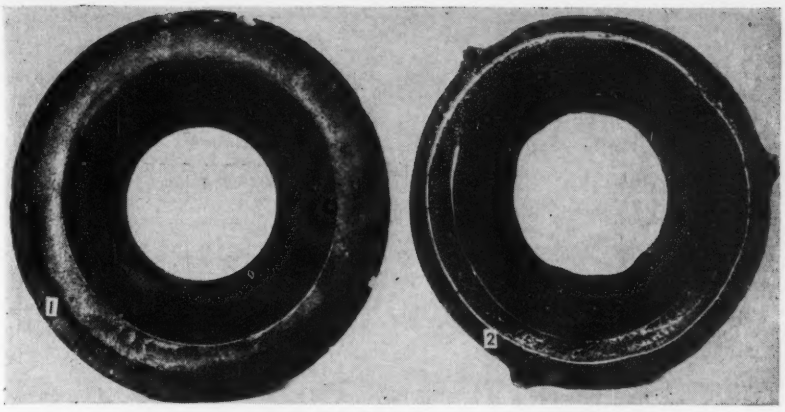


Figure 1—Apex discs after use in beneficiation of Taconite iron ore. (1) KT silicon carbide disc after 16 weeks; (2) Nihard steel casting after three to six weeks.

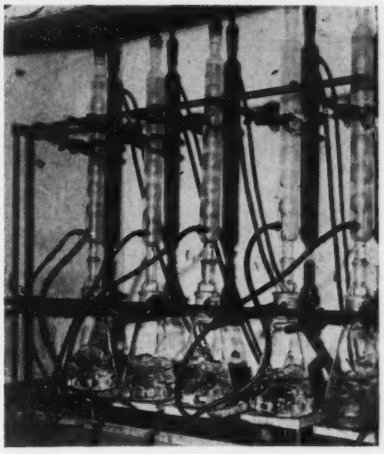


Figure 2—Corrosion tests in boiling solutions.

Corrosion Resistance of Dense, Impermeable Silicon Carbide*

By R. E. DIAL and G. E. MANGSEN

Abstract

Corrosion data are presented for dense, impermeable silicon carbide in various media. Results are given for static corrosion tests in aqueous solutions of acids, alkalies, and salts; in fused salts and molten metals up to 900 C; and in gases up to 1000 C. The corrosion resistance of the material was found to be good in most acid solutions and poor in strong alkalies. The resistance in fused salts, molten metals and gases varied with the corroding medium.

6.6.6, 4.3.2, 4.3.3, 4.7, 3.4.6

Introduction

CERAMIC MATERIALS are highly resistant to many corrosive environments. But in many cases it is impossible to predict their behavior under a given environment with any degree of certainty owing to a lack of engineering data.

To help close this gap, the Research and Development Division of The Carborundum Company set up a program aimed at supplying such data for the various ceramic products that the company manufactures. Although the program is still in its initial stages and final test procedures have not been arrived at in all cases, some preliminary data have been obtained for one of the company's products. This product is a dense, impermeable grade of silicon carbide which is currently being produced on a pilot-plant scale.

The present paper gives the corrosion resistance that was measured for this material under a number of different corrosive environments. In general, the test conditions were designed to simulate possible industrial applications.

Description of Material

The material is designated by the company as "KT" silicon carbide. It is formed by conventional ceramic techniques, such as pressing in steel molds, casting, or extruding. Large intricate shapes can be formed. After forming, the parts are subjected to a special high temperature treatment producing dense, self-bonded bodies. The surface of the material is rather rough due to crystal growth during the process. A smooth, dense surface can be produced using diamond grinding techniques.

★ Submitted for publication May 2, 1960. A paper presented at the 16th Annual Conference, National Association of Corrosion Engineers, Dallas, Texas, March 14-18, 1960.

TABLE 1—Corrosion of "KT" Silicon Carbide In Hydrochloric Acid

Percent HCl	Temp., Degrees C	Time, Hours	Avg. Corrosion Rate, MPY
20	Boiling	1008	0.1
20	175*	144	—0.1
20	200*	144	0.3
20	225*	144	0.5
37	Boiling	144	0.0
37	200*	48	0.0

* Under pressure.

TABLE 2—Corrosion of "KT" Silicon Carbide in Nitric Acid

Percent HNO_3	Temp., Degrees C	Time, Hours	Avg. Corrosion Rate, MPY
30	Boiling	144	0.2
50	Boiling	1008	0.0
50	200*	144	4.0
70	Boiling	144	0.2
70	200*	144	1.9
70	225*	144	1.0

* Under pressure.

TABLE 3—Corrosion of "KT" Silicon Carbide In Sulfuric Acid

Percent H_2SO_4	Temp., Degrees C	Time, Hours	Avg. Corrosion Rate, MPY
60	Boiling	144	0.0
60	200*	144	—0.3
80	Boiling	1008	—0.1
95	Boiling	144	—0.8
95	200*	288	—0.2
95	225*	144	1.2

* Under pressure.

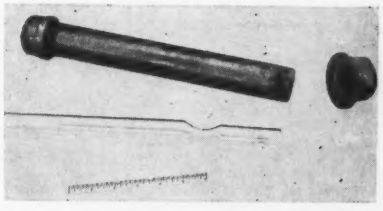


Figure 3—Apparatus for high temperature corrosion tests in acids.

Mangsen

Dial

ROY E. DIAL is supervising engineer in the engineering research branch of Carborundum's Central Research and Development Laboratories Niagara Falls, N. Y. Formerly he was a research chemist for the Alcoa Research Laboratories and General Aniline and Film Corporation. He has a BS and PhD from the University of Illinois.

G. E. MANGSEN was granted his BS degree in chemistry from Worcester Polytechnic Institute in 1931 and his MS degree in chemical engineering from Massachusetts Institute of Technology in 1932. He then became employed by The Fitchburg Paper Company and later the Norton Company. Since joining The Carborundum Company in 1946, his activities have included the development of ceramic bonds for abrasive articles, hot pressing of ceramics, and corrosion resistance of ceramics. He is presently employed as research engineer in the Applied Research Branch of the Research and Development Division.

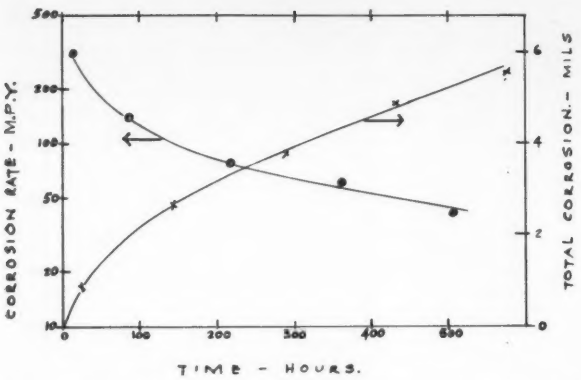


Figure 4—Corrosion of KT silicon carbide in 40 percent HF-10 percent HNO_3 at 60 C.

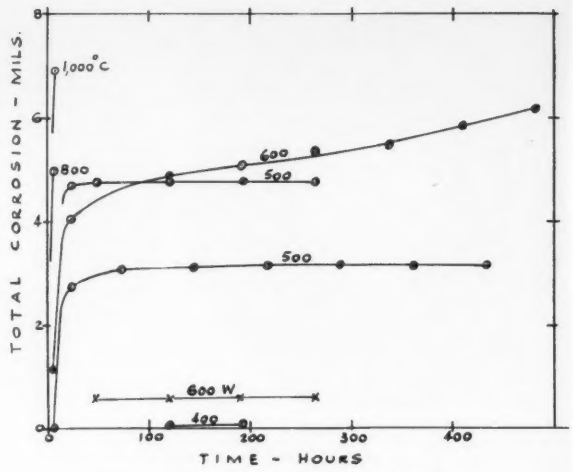


Figure 5—Corrosion of KT silicon carbide in chlorine gas.

TABLE 4—Corrosion of "KT" Silicon Carbide In Phosphoric Acid

Percent H_3PO_4	Temp., Degrees C	Time, Hours	Avg. Corrosion Rate, MPY
40	Boiling	144	0.0
60	Boiling	1008	0.0
60	200*	144	—0.1
85	Boiling	144	2.3
85	200*	288	0.5
85	225*	144	0.1

* Under pressure.

A typical chemical composition is as follows:

SiC	96.5
Free Si	2.5
Free C	0.4
Al	0.4
Fe	0.2

Some of the more interesting physical properties of "KT" silicon carbide are listed below:

Apparent specific gravity, g/cc .....3.10 minimum (Theoretical S. G., 3.22 g/cc)

Maximum working temperatures
Inert atmosphere .....2300 C
Oxidizing atmosphere .....1650 C

Abrasion resistance .....Excellent

Compressive strength, 10^3 psi,
25 C 150

Flexural strength, 10^3 psi
25 C 24
1200 C 25
1500 C 18

Modulus of elasticity, 10^6 psi
25 C 68.5
1200 C 61.5
1500 C 49.4

Thermal conductivity, cal/(cm) (sec) (°C)
400 C 0.170
1000 C 0.110

Permeability .....0 percent

Thermal shock resistance....Excellent

Hardness (Knoop 100) 2500-3000

Absorption of thermal neutrons .....Low

Electric Resistivity, ohm-cm
25 C .....about 0.13
1100 C .....about 0.05

Applications where the "KT" material has already been used successfully include (1) wear sleeves, centri-cleaner tips, and flat-box covers in the pulp and paper industries, (2) Apex discs for the beneficiation of Taconite iron ore (see Figure 1), (3) Valve seats for sulfuric acid-nickel ore slurry at 204 C, (4) tap-out blocks for reverberatory furnaces used for melting aluminum, (5) nozzles for high velocity acid and abrasive slurries, (6) metering orifices for corrosive chemical service, and (7) heat exchangers and muffle tubes for high-temperature furnaces. In addition, the material has shown promise as a nose cone material (1900 C test temperature in air), as a rocket nozzle material in liquid fuel systems, and

TABLE 5—Corrosion of "KT" SiC in Miscellaneous Aqueous Solutions

Test Conditions	Incr. Time, Hrs.	Acc. Time, Hrs.	Acc. Loss, Mils	Avg. Corr. Rate, MPY	
				Incr.	Acc.
40% HF–10% HNO_3 at 60 C	24	24	.862	315	315
	120	144	2.681	133	163
	144	288	3.971	78.4	121
	144	432	4.989	61.9	101
	144	576	5.674	41.7	86.3
Boiling 50% NaOH	24	...	6.090	2220	....
Boiling 25% NaOH	144	...	1.204	73.3	....
Boiling 10% Na_2SO_4	144	144	.003	0.2	0.2
	144	288	.005	0.1	0.2
Boiling 10% Na_2CO_3	144	144	.454(1)	27.6	27.6
	144	288	.440	—0.8	13.4
	144	432	.309	—8.0	6.3
	144	576	.182	—7.7	2.8
	144	720	—.035	—13.2	—0.4
	144	864	—.317	—17.1	—3.2
	144	1008	—.386(2)	—4.2	—3.4

(1) Equivalent to a loss in weight of 357 MD (mg/dm²).
(2) Equivalent to a gain in weight of 304 MD.

TABLE 6—Corrosion of "KT" SiC in Fused Salts and Caustic

Test Conditions	Time, Hours	Loss, mils	Avg. Corr. Rate, MPY
Fused NaOH 350 C	24	1.560	569
Fused NaOH 500 C	24	29.83	10,890
Fused Na_2CO_3 900 C	<24	>.320	>120
Fused LiCl 900 C	24	.929	339
Fused NaCl 900 C	24	—.008	—3.1
	72	.010	1.3
Fused KCl 900 C	28	.341	107
Fused $MgCl_2$ 900 C	24	.136	49.8
Fused $CaCl_2$ 900 C	24	2.694	983
Fused LiF 900 C	24	1.946	710

TABLE 7—Corrosion of "KT" SiC in Molten Metals

Test Conditions	Time, Hours	Loss, mils	Avg. Corr. Rate, MPY
Molten Al at 700 C	72	.459	55.8
Molten Al at 900 C	24	.027	9.8
	72	Severely Attacked	
Molten Sn at 400 C	24	—.005	—1.8
Molten Pb at 600 C	24	—.029	—10.6 (—22.7 MDD)
Molten Bi at 600 C	22	.079	31.5
Molten Mg at 750 C	24	.482	176
Molten Mg at 800 C	24	Severely Attacked	
Molten Zn at 600 C	24	.033	12.0
	72	.039	4.8

as a low neutron absorbing material for gas-cooled nuclear reactors.

Experimental Procedure

The samples for corrosion tests were cut from the interior of a larger piece of "KT" silicon carbide. They were 2 inches x ½ inch x ¼ inch in size with a density of 3.14 g/cc. For some tests, high density, low density, and desiliconized samples were made to size. No grinding or other treatment was employed on the surfaces of these latter samples. All samples, as received, were measured, washed in distilled water, dried at 70 C, and weighed. Some samples were reused after polishing the surface with a 400 grit diamond wheel to remove 0.002 inch from each surface.

Corrosion tests were conducted in boiling aqueous solutions of C. P. hydrochloric, sulfuric, nitric, and phosphoric acids under reflux according to ASTM designation A-262-52-T, "Boiling Nitric Acid Test for Corrosion-Resistant Steels." The apparatus is shown in Figure 2. Tests in acids also were conducted at temperatures above the boiling point, under pressure, in sealed Pyrex tubes up to 225 C. The sealed tubes were placed in capped iron pipe casings as shown in Figure 3. The assemblies were then placed in an oven at the desired temperature. The measured time interval began when the temperature of the Pyrex tube, measured by thermocouple, came within 5 C of the desired test temperature. The samples were weighed to the nearest 0.1 mg and the solution concentrations determined before and after test. The surface was examined, visually and microscopically, for pits and unusual deposits before and after test. X-ray diffraction analysis was performed on deposits when it seemed warranted. The main criterion for evaluating tests was weight loss, from which mils per year (mpy) loss was calculated.

High temperature molten metal and fused salt experiments were conducted in an electrically heated pot-furnace under static conditions. The sample and enough medium were charged into a crucible so that on fusion of the medium the sample was covered. The tests were, in most cases, conducted in an argon atmosphere. Where the crucible and medium were not subject to reaction with air, air was used. Graphite crucibles were used to contain the fused salts and zirconia crucibles to contain the molten metals. After test, the samples were lifted out of the medium and allowed to cool in the furnace as the medium and furnace cooled. Salts were dissolved from the sample with water and metals were removed with acids. When the samples were cleaned, they were examined in the normal manner.

Gas corrosion tests at high temperature were performed in a tube furnace with a one inch fused silica tube. The rectangular sample was pushed into the tube to the center of the furnace. No holder was needed because the sample touched the tube only along two edges allowing good flow of gas around the sample. After the sample was inserted inside the cold tube and furnace, the test gas was started and the temperature raised to the proper level and automatically controlled for the specified length of time. The sample was then cooled in the test gas before examination.

TABLE 8—Corrosion of "KT" SiC in Chlorine Gas

Test Conditions	Incr. Time, Hrs.	Acc. Time, Hrs.	Acc. Loss, Mils	Avg. Corr. Rate, MPY	
				Incr.	Acc.
Cl_2 at 200 C	6	6	0.000	0.0	0.0
	18	24	0.007	3.5	2.7
	24	48	0.002	—2.0	0.3
	24	72	0.002	0.0	0.2
	48	120	0.002	0.0	0.1
	72	192	0.001	—0.1	0.1
Wet Cl_2 at 200 C	6	6	0.000	0.0	0.0
	18	24	0.000	0.0	0.0
	24	48	—0.002	—0.9	—0.4
	72	120	—0.001	0.1	—0.1
Cl_2 at 300 C	6	6	0.003	4.5	4.5
	18	24	0.004	0.3	1.3
	24	48	0.002	—0.4	0.4
	72	120	0.008	0.7	0.6
	72	192	0.007	—0.1	0.3
	72	264	0.009	0.2	0.3
	72	336	0.010	0.2	0.3
Cl_2 at 400 C	6	6	0.005	7.2	7.2
	18	24	0.008	1.5	2.9
	24	48	0.008	0.0	1.5
	72	120	0.012	0.4	0.9
	72	192	0.015	0.4	0.7
	72	264	0.020	0.6	0.7
	72	336	0.035	1.9	0.9
Wet Cl_2 at 400 C	48	48	0.013	2.4	2.4
	72	120	0.019	0.7	1.4
	72	192	0.021	0.2	1.0
	72	264	0.018	—0.3	0.6
Cl_2 at 500 C 1st. run	6	6	0.005	8.0	8.0
	18	24	2.706	1314	988
	48	72	3.098	71.5	377
	72	144	3.120	2.8	190
	72	216	3.133	1.5	127
	72	288	3.132	—0.1	95.3
	72	360	3.124	—1.0	76.0
	72	432	3.145	2.5	63.8
Cl_2 at 500 C 2nd. run	24	24	4.699	1715	1715
	24	48	4.730	11.4	863
	72	120	4.751	2.5	347
	72	192	4.792	5.1	219
	72	264	4.794	0.2	159
Cl_2 at 600 C	6	6	1.092	1594	1594
	18	24	3.987	1409	1455
	96	120	4.843	78.1	354
	72	192	5.044	24.4	230
	72	264	5.274	28.0	175
	72	336	5.422	18.0	141
	72	408	5.782	43.8	124
	72	480	6.098	38.4	111
Wet Cl_2 at 600 C	48	48	0.579	105.6	105.6
	72	120	0.594	1.9	43.3
	72	192	0.610	2.0	27.8
	72	264	0.608	—0.3	20.2
Cl_2 at 800 C	6	...	5.072	7405	.....
Cl_2 at 1000 C	6	...	7.247	10580	.....

TABLE 9—Corrosion of "KT" SiC in Other Gases

Test Conditions	Incr. Time, Hrs.	Acc. Time, Hrs.	Acc. Loss, Mils	Avg. Corr. Rate, MPY	
				Incr.	Acc.
CO_2 at 1000 C	72	72	.200	24.4	24.4
	72	144	.188	—1.5	11.4
	72	216	.182	—0.8	7.4
O_2 at 500 C	72	72	.863	105	105
	72	144	1.152	35.2	70.1
	72	216	1.215	7.6	49.3
	72	288	1.320	12.8	40.1
Air at 1000 C	72	...	—.003	—0.3	....
H_2 at 1000 C	72	...	—.003	—0.4	....

Results And Discussion

Corrosion resistance of "KT" silicon carbide was found to be excellent in dilute and concentrated solutions of HCl, HNO_3, H_2SO_4, and H_3PO_4 at temperatures up to 225 C.; the results are given in Tables 1-4. Tests on individually fabricated pieces gave practically the same results as on pieces cut from the interior of a large piece.

Table 5 shows corrosion data for miscellaneous aqueous solutions. In the extremely corrosive solution of 40 percent HF-10 percent HNO_3 at 60 C, the initial corrosion rate was high at 315 mpy, but the rate dropped quite rapidly to 42 mpy after 576 hours (24 days). The total loss in 576 hours was less than six mils. The results are shown graphically in Figure 4.

The corrosion rate in boiling 25 percent NaOH was high, and in 50 per-

cent NaOH extremely high. The large increase in corrosion with concentration indicates that corrosion resistance may be satisfactory at lower concentrations.

Corrosion resistance in boiling 10 percent Na_2CO_3 was excellent. The results in boiling 10 percent Na_2CO_3 indicated good corrosion resistance by the formation of a protective coating; x-ray analysis indicated a mixture of carbonates and bicarbonates in this coating.

Table 6 contains data on fused salts and caustic. Corrosion resistance in fused NaOH and in fused Na_2CO_3 was very poor. At 900 C, the resistance to NaCl, $MgCl_2$, KCl, LiCl, LiF and $CaCl_2$ varied from good to poor in the order listed.

Corrosion resistance in molten metals varied from excellent to very poor as shown in Table 7. The results indicated good resistance to tin at 400 C and lead at 600 C, fair resistance to bismuth and zinc at 600 C, and poor resistance to magnesium at 750-800 C. Results with aluminum are conflicting, ranging from fair to very poor. The severe attack by aluminum does not agree with the experience of the aluminum industry, where "KT" silicon carbide has given satisfactory service in contact with aluminum at 800 C.

Corrosion in chlorine is shown in Table 8 and graphically in Figure 5. The 600 W curve is for a test in wet chlorine at 600 C; the other curves are for tests in dry chlorine at the indicated temperatures in degrees C. Corrosion resistance is excellent up to 500 C in dry chlorine and 600 C in wet chlorine. Although the rate of corrosion at 500 C is high initially, it decreases rapidly to practically zero. At 600 C the rate levels off to 30-40 mpy. Tests on individually fabricated pieces indicated higher initial rates; otherwise the results were the same as for the interior pieces.

Limited data on corrosion of "KT" silicon carbide in other gasses are given in Table 9. The results indicate good resistance to carbon dioxide, hydrogen, and air at 1000 C; moderate resistance is indicated for pure oxygen at 500 C.

Summary

The corrosion resistance of "KT" silicon carbide to various possible corroding media was measured. The results obtained under the described test conditions showed that the material had excellent resistance to HCl, HNO_3, H_2SO_4, H_3PO_4 but that it had relatively poor resistance to 40 percent HF-10 percent HNO_3 and to strong alkalies. The resistance to molten salts and molten metals was good in some cases and poor in others.

The material showed good resistance to high-temperature attack by carbon dioxide, hydrogen, and air. In pure oxygen at 500 C, however, the resistance was only moderate.

DISCUSSION

Questions by H. Howard Bennett, Mobil Oil Co., Paulsboro, N. J.:

1. What are the dimensional tolerances to which KT silicon carbide can be fabricated?

2. What are the maximum sizes to which parts or articles can be fabricated?

Replies by Roy E. Dial:

1. KT silicon carbide can be fabricated now to within 0.0050-inch dimensional tolerance. There is no theoretical limit. As fired, with no polishing, tolerance is 0.013-0.015-inch, and with normal diamond grinding it is 0.005-inch.

2. Maximum sizes now being fabricated are 12-inch diameters by 12 inches long, and also 2-inch diameters by 24 inches long. Before long, pieces 4 inches in diameter by 48 inches long will be fabricated.

Comments by John J. Moran, 67 Wall St., New York, N. Y.:

Will you comment upon the compatibility of silicon carbide in intimate contact with engineering alloys (i.e., stainless steels or high nickel alloys) at high temperatures, say in the vicinity of 1950-2000 F. We have observed that under certain conditions a reaction detrimental to the metal will occur.

Reply by Roy E. Dial:

It is not expected that iron will react with silicon carbide at these temperatures to form Fe_3C, because silicon carbide is more stable than Fe_3C thermodynamically up to temperatures way above 2000 F. Not enough thermodynamic data are available on nickel and silicides to make other predictions. Analysis of reaction product of Inconel and silicon carbide showed high silicon and carbon in the metal phase. X-ray analysis showed nickel and chromium silicides as possibly present.

Any discussion of this article not published above will appear in June, 1961 issue.

Inhibition of Corrosion of Commercial Aluminum In Alkaline Solutions*

By J. SUNDARARAJAN and T. L. RAMA CHAR

Abstract

The corrosion rates for commercial aluminum, containing 4 percent manganese and 3 percent iron, have been determined in sodium hydroxide solutions under different conditions. The inhibitor efficiencies have been calculated for the following substances, the efficiency decreasing from 90 to 60 percent in the order: agar-agar, gum-acaciae, dextrin, gelatin, glue. Corrosion potentials have been measured with and without dextrin inhibitor, and cathodic and anodic polarization studies made. The results show that the dissolution of the metal is electrochemical in character. The corrosion process appears to be under mixed control with predominance of action of dextrin inhibitor on the anodic areas of the metal surface. 6.4.2, 4.3.3, 5.8.2

Introduction

ALUMINUM AND its alloys have found steadily increasing use in recent years. In India this trend has been particularly marked owing to the metal's ready availability, the shortage of the common non-ferrous metals, and the unsatisfactory steel position. Aluminum has good corrosion resistance, particularly in neutral media, but in strong acids or alkalies the metal is usually attacked. Its corrosion behavior can be modified by the addition of alloying elements which are introduced in order to obtain the desirable properties. Another approach is to protect the metal in corrosive environments through the use of inhibitors.

The dissolution of aluminum in sodium hydroxide solutions has been studied by Streicher,[1,2] Straumanis and Brakss,[3,4] McKee and Brown,[5] and Petrocelli.[6] Unlike the case for acid environments, satisfactory inhibitors have not been found for the corrosion of aluminum in alkaline solutions.[7] Previous reports[7–10] state that the following substances in alkalies are effective: glue, glucose, gelatin, agar-agar, gum arabic, silicate and permanganate. But detailed studies of an academic character are lacking in the published work on inhibition. Streicher has studied the corrosion potentials as well as the polarization of pure aluminum in alkaline solutions,[1] and also briefly reported corrosion potential work with inhibitors.[8] Polarization studies for pure aluminum in sodium hydroxide solutions have also been made by Petrocelli.[6] The present work formed part of the general program on the corrosion of aluminum of different compositions and its inhibition in alkaline and acid solutions. The results on corrosion rates, inhibitor efficiencies, corrosion potentials and polarization have been briefly reported in previous communications from this laboratory.[11–17] This paper presents in detail the investigations on the inhibition of the corrosion of commercial aluminum in alkaline solutions.

Sundararajan Rama Char

J. SUNDARARAJAN is doing his doctoral work on the inhibition of corrosion of aluminum in the Electrochemistry Laboratory of the Indian Institute of Science, Bangalore. He holds the B.Sc. and M.Sc. (in Physical Chemistry) degrees, and has published several papers on corrosion and related topics.

T. L. RAMA CHAR is Assistant Professor of Physical Chemistry at the Indian Institute of Science, Bangalore. He holds the B.Sc., M.Sc. and Ph.D. (1940) degrees. Except for two years on war service, he has been associated with the Indian Institute of Science since 1939. He directs electrochemical research, specializing in electrodeposition and corrosion of metals. He is the author of more than 80 papers and is a member of a number of technical and scientific societies.

Experimental

The aluminum sheet (SWG22) was a commercial sample whose analysis was as follows: Al 92 percent, Mn 4 percent, Fe 3 percent, and Si and others 1 percent (maximum). The metal coupon was punched in one piece with a steel die. It was of a circular design to minimize the edge effects, diameter 2 cms with a handle 3 cms long and 0.3 cm wide, the total weight being approximately 825 mg. The handle was coated with a plastic from a chloroform solution leaving only the circular portion of surface area 6.3 sq cms exposed to the corrosive medium.

A series of samples were immersed in beakers containing 60 ml sodium hydroxide solution. This volume was found to be sufficient for the area of the specimen exposed. The pre-treatment of the coupon was as follows: polishing with emery (300), washing, rinsing for 3 minutes in alkali of the same concentration as is used for corrosion tests, wiping off the black film, washing in alcohol, drying. This procedure was necessary in order to obtain reproducible corrosion rates within 1 percent. The corrosion rates of aluminum were determined under the following conditions: (a) concentration of sodium hydroxide 0.1, 0.2, 0.3, 0.4, 0.6, 0.93 N; (b) temperature 32, 42, 52 C

★ Submitted for publication January 19, 1960. A paper presented at the 16th Annual Conference, National Association of Corrosion Engineers, Dallas, Texas, March 14-18, 1960.

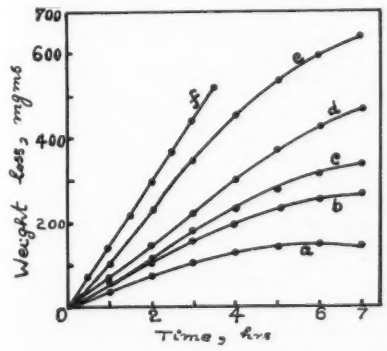


Figure 1—Effect of time on corrosion rate. Temperature, 32 C; concentration of alkali: (a) 0.1N, (b) 0.2N, (c) 0.3N, (d) 0.4N, (e) 0.6N, (f) 0.93N.

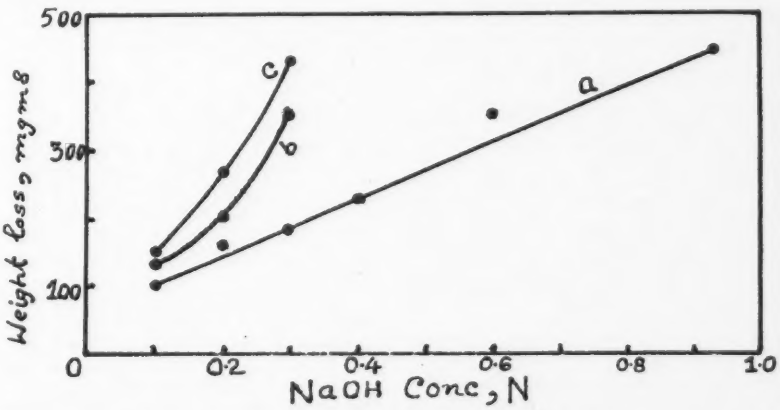


Figure 2—Effect of alkali concentration on corrosion rate. Time 3 hours; temperature: (a) 32 C, (b) 42 C, (c) 52 C.

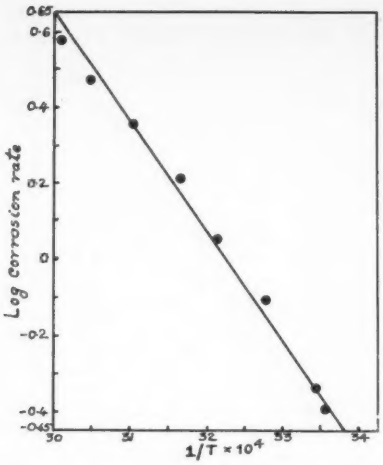


Figure 3—Log. corrosion rate against 1/T. Concentration of alkali is 0.3N.

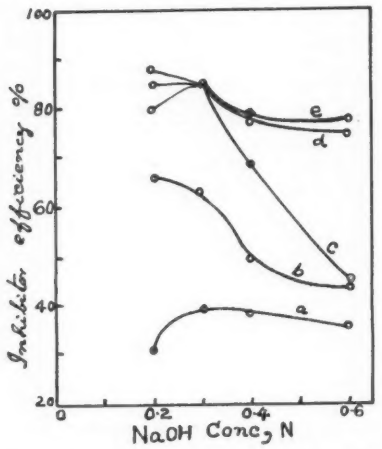


Figure 4—Effect of alkali concentration on inhibitor efficiency. Temperature, 32 C, time 3 hours, inhibitor: (a) glue, (b) gelatin, (c) dextrin, (d) gum acaciae, (e) agar-agar. Inhibitor concentration: 2 g/l.

and (c) immersion period, 1, 2, 3, 4, 5, 6, 7 hours.

Inhibitor efficiencies were determined with the following substances: agar-agar (B.D.H.), gum acaciae (powder, Allen Co.), dextrin (yellow, Merck), glue (flake, commercial), gelatin (powder, Oxoid Co.), the concentration ranging from 2 to 20 g/l. Dextrin and agar-agar were directly added to the alkali solutions; the other inhibitors were dispersed in the same alkali before transferring them to the corrosive medium. Conditions were so adjusted that the weight losses were not too great as compared to the initial weights of the coupons. At the end of the immersion period the geometrical shape of the coupon remained unaltered. The inhibitor efficiencies were calculated from the weight loss and were accurate to ±2 percent.

The potentials of aluminum in sodium hydroxide solutions with and without dextrin inhibitor were measured against a saturated calomel electrode with an intermediate bridge (whose capillary

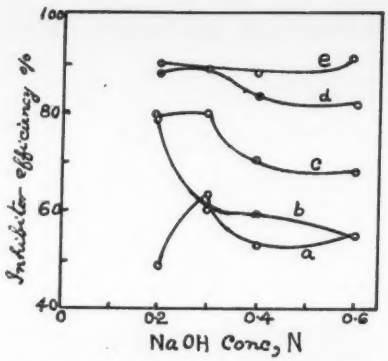


Figure 5—Effect of alkali concentration on inhibitor efficiency. Temperature, 32 C, time 3 hours, inhibitor: (a) glue, (b) gelatin, (c) dextrin, (d) gum acaciae, (e) agar-agar. Inhibitor concentration, 10 g/l.

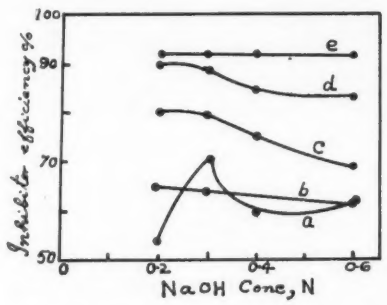


Figure 6—Effect of alkali concentration on inhibitor efficiency. Temperature, 32 C, time 3 hours, inhibitor: (a) glue, (b) gelatin, (c) dextrin, (d) gum acaciae, (e) agar-agar. Inhibitor concentration: 20 g/l.

tip was 2 mm. away from the center of the specimen) containing the same concentration of alkali. It took about 30 minutes to obtain the steady state potential value. The experimental conditions were: (a) concentration of sodium hydroxide, 0.1, 0.2, 0.3 N, (b) concentration of dextrin 0.6, 1.25, 2, 2.5, 5, 10, 15, 20, 30 g/l, (c) temperature 32 ±0.1 C and (d) immersion period 2 hours.

The potential values (on hydrogen scale throughout) were reproducible within ±3 mv up to 0.2N alkali, and ±6 mv at higher concentrations. Polarization studies were made with aluminum as cathode or anode in 0.3N NaOH at 32 C, the other electrode being one of platinum of the same dimension. For these experiments an H-type glass cell with porous partition to separate the two compartments was used. It also contained a built-in capillary to make connection to the reference electrode. The back of the coupon was stopped off with plastic coating. The current density was increased progressively in the range 0-1.87 amp/dm² on the basis of apparent surface area of 3.14 sq. cms., the immersion period being 2 hours.

Measurements were made of the weight loss and electrode potential with and without inhibitor. The weight loss values were quite reproducible as before. The potential values were reproducible within ±5 mv for the cathode where the polarization is very small.

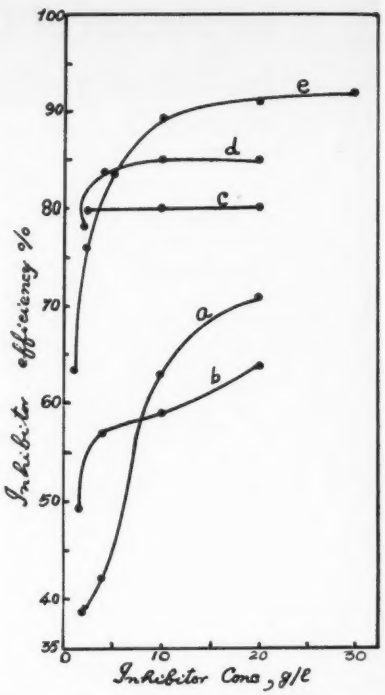


Figure 7—Effect of inhibitor concentration on inhibitor efficiency. Temperature, 32 C, time 4 hours, inhibitor: (a) glue, (b) gelatin, (c) dextrin, (d) gum acaciae, (e) agar-agar. Alkali concentration: 0.3N.

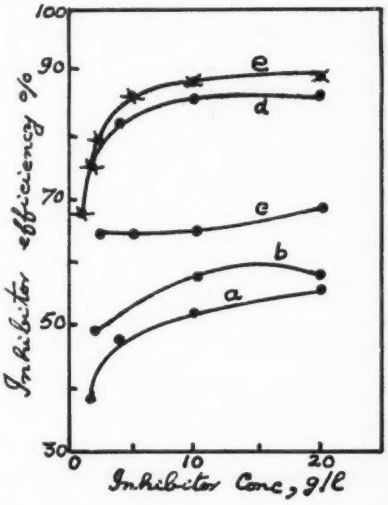


Figure 8—Effect of inhibitor concentration on inhibitor efficiency. Temperature, 32 C, time 4 hours, inhibitor: (a) glue, (b) gelatin, (c) dextrin, (d) gum acaciae, (e) agar-agar. Alkali concentration, 0.4N.

But on the anode side there was appreciable polarization and the potentials were less reproducible, being accurate within ±10 mv.

Experimental Results

Figures 1 to 19 present the experimental results. All the data have not been covered graphically so as to avoid overlapping, but only the more significant ones.

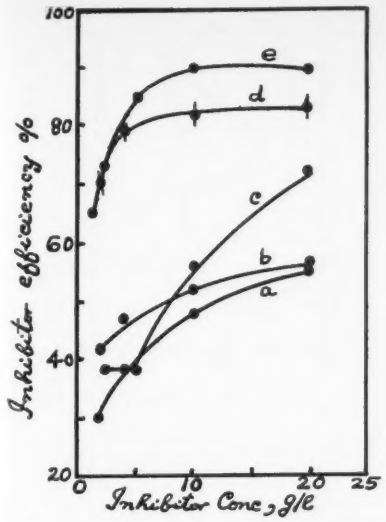


Figure 9—Effect on inhibitor concentration on inhibitor efficiency. Temperature, 32 C, time 4 hours, inhibitor: (a) glue, (b) gelatin, (c) dextrin, (d) gum acaciae, (e) agar-agar. Alkali concentration: 0.6N.

Corrosion Rates

The weight loss increases with increase in the immersion period, alkali concentration or temperature. The weight loss-time curves are linear up to about 5 hours immersion; therefore there is a decrease in the corrosion rate. The weight loss-alkali concentration curve is linear at 32 C. The plot of log corrosion rate against the reciprocal of temperature gives a straight line (Figures 1-3).

Inhibitor Efficiencies

With increase in the alkali concentration the inhibitor efficiency generally decreases, but remains practically unchanged for the relatively more efficient inhibitors, agar-agar and gum acaciae. The figures show that glue and gelatin are less efficient as inhibitors, dextrin occupying a medium position in this respect (Figures 4-6). The efficiency increases with increase in inhibitor concentration up to a certain value, the optimum, beyond which it is practically constant. The optimum concentration increases with decrease in the efficiency of the inhibitor (Figures 7-9). The effect of the immersion period on inhibitor efficiency is not appreciable for inhibitors with high efficiency; in other cases the efficiency decreases to some extent with time (Figures 10-12).

Corrosion Potentials

Potential measurements were confined to dextrin since the potential values were not consistently reproducible with other inhibitors. The steady state value of the corrosion potential becomes more positive with increase in the concentration of dextrin, and this plot gives an adsorption isotherm curve. For the same inhibitor concentration the potential becomes more negative with increase in the concentration of alkali (Figure 13). Figure 14 gives the straight line plot for $C/\Delta E$ against C, where C is the inhibitor concentration g/l, and

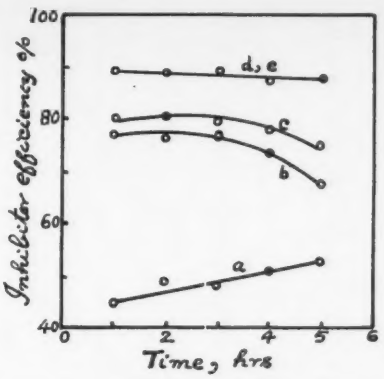


Figure 10—Effect of time on inhibitor efficiency. Temperature 32 C, inhibitor concentration, 10 g/l. Inhibitor: (a) glue, (b) gelatin, (c) dextrin, (d) gum acaciae, (e) agar-agar. Alkali concentration: 0.2N.

ΔE is the difference in the steady state potential with and without inhibitor.

Polarization

Impressed current has no effect on the corrosion rate of the aluminum cathode with and without the inhibitor. At the same current density, however, the corrosion rate is considerably decreased with the addition of dextrin (Figure 16). On the anode side, increase in the current density increases the corrosion rate, and with the inhibitor the corrosion rate is diminished for a given current density. With impressed current and inhibitor, the inhibitor efficiency decreases with increase in the current density (Figure 17).

The cathode potential increases with increase in the current density, but the polarization is small—the maximum value being of the order of 30 and 40 mv respectively without and with inhibitor (Figure 16). This also shows that there is only a very small rise in the polarization due to dextrin. The anode potential decreases (i.e., becomes more positive), with increase in the current density. The anode polarization is comparatively greater than that on the cathode side, the maximum value being of the order of 40 and 120 mv respectively without and with inhibitor (Figure 17).

Discussion

Corrosion Rates

Aluminum dissolves in sodium hydroxide to give a precipitate of aluminum hydroxide which in turn dissolves in excess of alkali to form a complex sodium aluminate. If the aluminum is alloyed with other elements the picture will be altered. In the present case manganese and iron form the major alloying elements, and are precipitated in the solution. With pure aluminum one should expect a linearity for the corrosion rate-immersion period curves. Figure 1, however, shows as already stated that the linearity holds good up to about 5 hours, and thereafter there is a decrease in the corrosion rate due to surface deposition of corrosion products formed from the alloying elements. Work done in this laboratory has shown that with 99.5 percent aluminum there is only a very

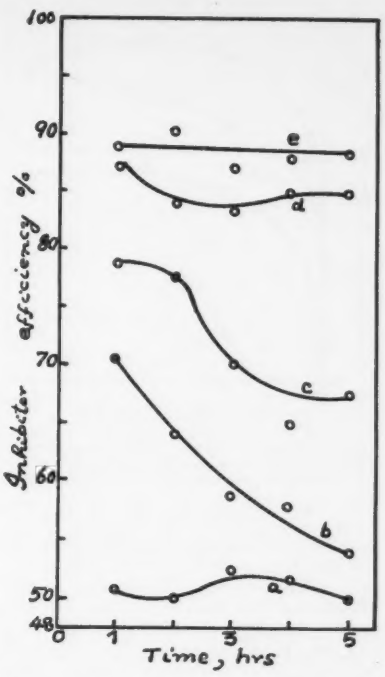


Figure 11—Effect of time on inhibitor efficiency. Temperature 32 C, inhibitor concentration, 10 g/l. Inhibitor: (a) glue, (b) gelatin, (c) dextrin, (d) gum acaciae, (e) agar-agar. Alkali concentration: 0.4N.

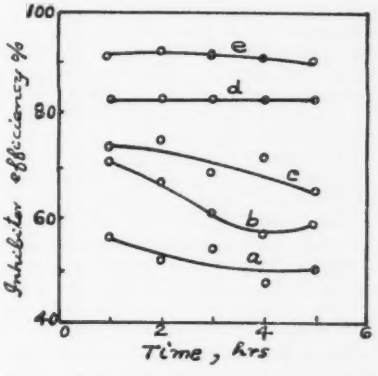


Figure 12—Effect of time on inhibitor efficiency. Temperature 32 C, inhibitor concentration, 20 g/l. Inhibitor: (a) glue, (b) gelatin, (c) dextrin, (d) gum acaciae, (e) agar-agar. Alkali concentration: 0.6N.

thin deposit on the metal surface during dissolution, and the linearity of the above curves holds good beyond 7 hours[18].

The corrosion rate is increased by the presence of manganese and iron. Streicher[2] as well as Straumanis and Brakss[4] have also observed that iron increases the rate of dissolution of aluminum in sodium hydroxide. Streicher has explained this by stating that the alloying constituents form the local cathodes, and when dissolution starts the precipitates formed by the constituents also act as cathodes. The growth of the precipitate increases the total cathodic area. Since the anodic areas are not greatly diminished, this growth of precipitate increases the local anode current density and ultimately the corrosion rate. The increase in the corro-

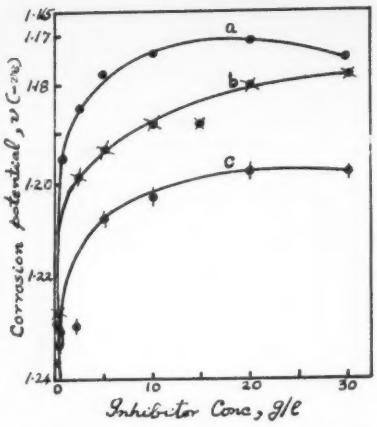


Figure 13—Effect of inhibitor concentration on corrosion potential. Temperature 32 C, time 2 hours; concentration of alkali: (a) 0.1N, (b) 0.2N, (c) 0.3N.

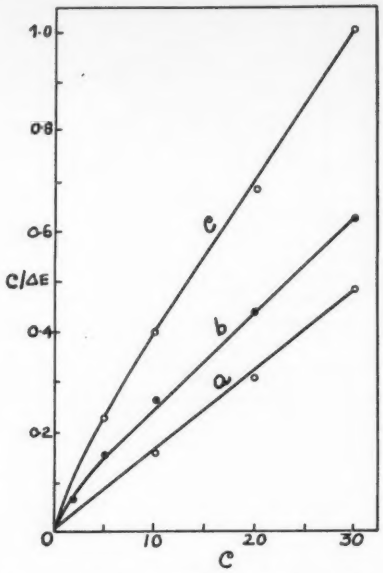


Figure 14—Plot of C/△E against C. Temperature 32 C; concentration of alkali: (a) 0.1N, (b) 0.2N, (c) 0.3N.

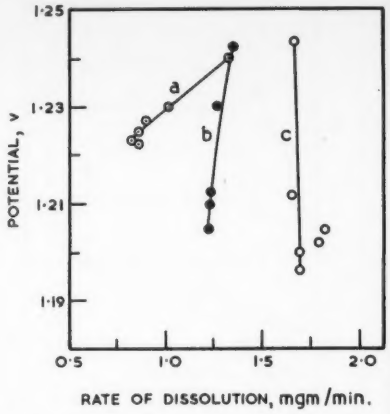


Figure 15—Local cell potential diagram. Temperature 32 C, exposed area 6.3 sq. cm.; concentration of alkali: (a) 0.3N, (b) 0.4N, (c) 0.6N.

sion rate by iron as the alloying element has also been attributed to its low hydrogen overvoltage, the iron acting as the cathode of the local cell.[4] Zinc with a higher hydrogen overvoltage than iron has been found to increase the corrosion rate of pure aluminum to a lesser extent than iron.[14] Aziz and Godard[19] have reported that manganese addition decreases the rate of pitting of aluminum.

The experimental results indicate that the observed linearity in the curves is due to the loosely adherent black deposit that forms on the aluminum surface during dissolution. Since the corrosive medium has access to metal surface the corrosion process is not hindered. With time, however, the deposit becomes fairly adherent and thick but still the metal is not completely blocked. At this stage the corrosion rate is decreased. The total anodic area perhaps remains constant resulting in a tendency towards a constancy in the corrosion rate as indicated in Figure 1. Katz[20] has stated that corrosion processes which are connected with the formation of a protective layer on the surface are not linear functions of time

Figure 2 shows that the corrosion rate-alkali concentration curves are practically linear. This is probably due to the fact that there are no disturbances on account of protective layer formation, the corrosion rate being governed by the concentration of the reactant. Streicher[1] has obtained the logarithmic relationship for this plot for 99.1 percent aluminum, whereas Straumanis and Brakss[3] have shown that the rate of solution of highest purity aluminum in sodium hydroxide up to 1N is proportional to the cube root of the alkali concentration. The difference in behavior in these cases could perhaps be attributed to the alloying elements in the metal. The experimental energy of activation of the rate controlling process in the dissolution of aluminum was calculated from Figure 3 by using the Arrhenius equation. The value was 13200 cals per mole, which checks well with the value 13700 cals per mole reported by Streicher.[1] He has also stated that the dissolution rate approximately doubles with an increase of 10 C in the temperature, and that this is generally considered to be true for homogeneous chemical reactions. The results reported in Figure 3 are roughly in conformity with this.

Corrosion rates were determined in a few cases in a nitrogen atmosphere and/or with agitation. The values were not altered. Petrocelli[6] also reports that there is no appreciable difference in the results when nitrogen is passed through solution, and concludes that oxygen reduction occurs only to a very small extent. Uhlig[21] has stated that generally aluminum alloys are relatively insensitive to the concentration of oxygen present in most aqueous solutions. The effect of agitation also indicates that the corrosion process is not diffusion controlled.

Inhibitor Efficiencies

The experimental results show that fairly satisfactory inhibition of the corrosion of aluminum in sodium hydroxide is possible with all the inhibitors used. Agar-agar and gum acaciae are very good in this respect, and dextrin comes next. Glue is comparatively the least efficient inhibitor in this group, gelatin being somewhat better. Gelatin, however, is not as good an inhibitor as is reported in literature.[7] Mixed inhibitors were tried, but do not offer any advantage. The following substances, reported to be inhibitors, gave a very low inhibitor efficiency: glucose, dextrose, permanganate, tungstate and phosphates. Permanganate gives a brown layer on the surface and accelerates corrosion; this phenomenon has been observed by Streicher at low concentrations.[8] Detailed data on these inhibitors are not available in literature for a comparison of the experimental results. However, all of them except dextrin have been mentioned as inhibitors for aluminum in sodium hydroxide.[7, 8, 10] Glue and gelatin are also inhibitors for iron in acid medium.[15]

Alkali concentration has no effect on the efficiency of agar-agar and gum acaciae, whereas in other cases the efficiency decreases with increase in concentration (Figures 4-6). It can be assumed that for the more efficient inhibitors the barrier layer is adequate enough to prevent an increase in the corrosion rate. In other cases there is access of the corrosive medium to the metal, with the result that the corrosion rate increases and inhibitor efficiency falls with increasing alkali concentration. Efficient inhibitors like agar-agar, gum acaciae and dextrin prevent the formation of the black deposit on the surface. The corrosion product cannot now function as local cathode, so that there is no increase in the anodic current density and consequent raise in corrosion rate.

Figures 7-9 show that an optimum concentration of inhibitor is required for adequate protection of the metal surface. The results have clearly shown that very small concentrations of these inhibitors are sufficient for protection of the metal surface. Detailed work of this type on the establishment of the optimum concentration and the effect of other variables is not to be found in published reports. Under similar conditions a smaller concentration of the more efficient inhibitor is equivalent to a large concentration of the less efficient one. If the inhibitor is efficient its efficiency should be practically independent of time, as is shown in Figures 10-12 for agar-agar and gum acaciae. In the case of glue, however, it is seen that the efficiency increases with time at a low alkali concentration of 0.2N, remains practically unaltered at 0.4N, and finally decreases with time when the alkali concentration reaches 0.6N. It may probably be due to the 'swelling' effect of the inhibitor at 0.2N.

Corrosion Potentials

Figure 13 records the steady state potential values under different conditions. An analysis has been made of the potential-time curves before the steady state is reached. The potential changes rapidly to a more positive value in about 15 min-

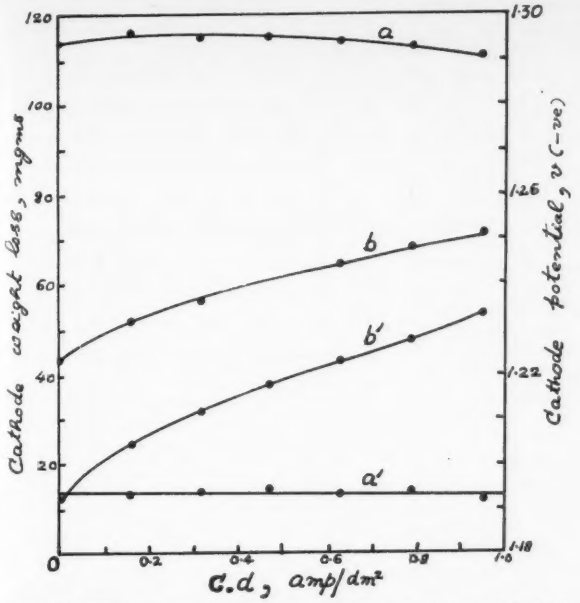


Figure 16—Effect of current density on corrosion rate and potential of the cathode. Temperature 32 C, time 2 hours, concentration of alkali 0.3N, concentration of dextrin 10 g/l; (a) corrosion rate, (a') corrosion rate with inhibitor, (b) potential, (b') potential with inhibitor.

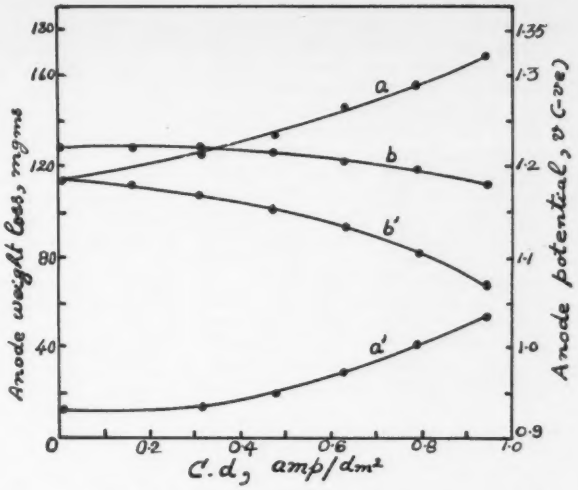


Figure 17—Effect of current density on corrosion rate and potential of the anode. Temperature 32 C, time 2 hours, concentration of alkali 0.3N, concentration of dextrin 10 g/l; (a) corrosion rate, (a') corrosion rate with inhibitor, (b) potential, (b') potential with inhibitor.

utes, then slowly in the same direction for 30 minutes. Next comes a small shift of 5-10 mv in the negative direction, followed by a period in which the potential remains practically constant. The curves with dextrin were similar. Addition of 10 g/l dextrin, the optimum value, shifts the potential in a more noble direction, the difference in the potential values with and without inhibitor being 62 mv at 0.1N alkali, 38 mv at 0.2N and 25 mv at 0.3N. This shows that a high concentration of dextrin is required for inhibition at 0.3N alkali, as confirmed by corrosion rate data.

The Langmuir type of adsorption (Figure 14) has been reported by Hackerman and Sudbury[22] for copper with amine inhibitor in acid solutions, and by Uhlig[23] for iron with chromate inhibitor in distilled water. A linear relationship was not obtained for the plot of log ΔE against log C, showing that the Fruendlich equation is not obeyed.

Polarization

The plot of the corrosion potential against corrosion rate for a given time gives a straight line for all alkali concentrations. This is the local cell potential diagram (Figure 15), and indicates that the dissolution of aluminum in alkaline solutions is electrochemical in character.[1] This is also supported by the work of Streicher,[2] and Petrocelli.[6] Brown and Mears[24] have provided proof for this mechanism in the case of aluminum in neutral alkali chloride solutions. The "difference effect" has been observed by Streicher[1] for aluminum in sodium hydroxide solutions. During the present investigations also this effect has been noted, and it provides additional proof for the electrochemical theory of corrosion.

The weight loss as well as polarization values show that cathodic protection of aluminum is not possible (Figure 16). This is because the local cathodes cannot be polarized to the open circuit potential of the local anodes by the external current. Anodic protection is also not possible by impressing high current densities. This is probably because there is little chance of any protective film being formed under these conditions. The anode weight loss curve of Figure 17 shows that it is necessary to impress at least about 0.4 amp/dm² before the local cell action disappears and there is linearity between weight loss and impressed current (curve a). When the above current density is reached it has been actually observed that there is no hydrogen evolution at the electrode. At this stage the difference effect also ceases.

The anode polarization has a maximum value of about 40 and 120 mv respectively without and with inhibitor. These values are greater than those on the cathode side, 30 and 40 mv respectively. Polarization studies with 99.5 percent aluminum have given the values 76 and 180 mv respectively for the anode under similar conditions.[16] This is in conformity with the 'polarization resistance' for these two alloys.[25]

The pH of 0.3N alkali solution is 13.24 as measured by the hydrogen electrode at 25 C. By the addition of dextrin 2 to 20 g/l the value is 13.21 to 13.16, there being no pH change. The conductivity of the solution is also not appreciably changed under these conditions.

Mechanism of Inhibition

The corrosion of aluminum in sodium hydroxide solutions is an electrochemical process, and its inhibition can take place by (a) reduction in the open circuit potential or (b) increasing the polarization of the cathode or the anode or both.[24]

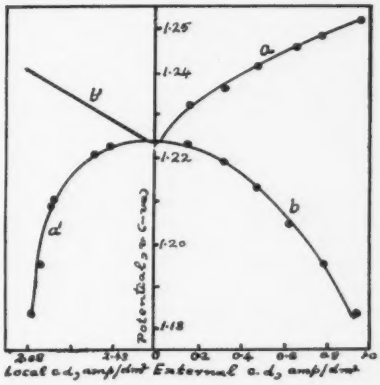


Figure 18—External and local cell polarization curves. Temperature 32 C, time 2 hours, concentration of alkali 0.3N; external polarization curves: (a) cathode, (b) anode; local cell polarization curves: (a') cathode, (b') anode.

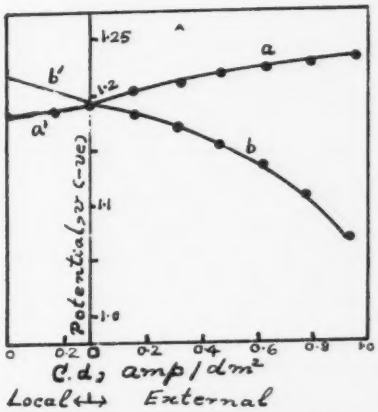


Figure 19—External and local cell polarization curves with inhibitor. Temperature 32 C, time 2 hours, concentration of alkali 0.3N, concentration of dextrin 10 g/l; external polarization curves: (a) cathode, (b) anode; local cell polarization curves: (a') cathode, (b') anode.

The observed shift in the open circuit potential by the addition of inhibitor is well reflected in the effect of the inhibitor on the anodic and cathodic regions. The cathode polarization is slightly increased whereas there is a significant increase in the polarization on the anode side. Figures 18 and 19 give the polarization curves without and with inhibitor respectively, the local cell polarization curves being reconstructed from weight loss measurements. Without inhibitor the corrosion is found to be under mixed control, with predominance of the cathodic process. Streicher has also come to similar conclusions.[1] The results tend to provide further proof that the surface deposition from the products of dissolution affect the cathodic areas and control the corrosion reaction.

The mixed control theory also holds good in the presence of dextrin. The inhibitor appears to have equal influence on the cathodic and anodic regions. The corrosion current is low with the result that the anode polarization is high (Figures 18 and 19). The function of the inhibitor seems to be to prevent the surface deposition and shift the emphasis to the anodic reaction. Figure 13 shows that ΔE is quite large at a low concentration of inhibitor and the differences become smaller with increasing concentration. Hackerman and Sudbury[23] attribute this to the coverage of the more active areas, the anodic regions at low concentrations; at the higher concentrations the more anodic surfaces are covered and the average cathodic value is approached.

Rakuzin[26] found that aluminum hydroxide adsorbs gum arabic from its aqueous solution irreversibly. This perhaps indicates that the inhibitor retards the dissolution of metal hydroxide in alkali resulting in a diminution in the corrosion rate. Yamaguchi[27] has suggested that colloidal corrosion products will protect the metal from further corrosion, by compactly covering the surface and forming a barrier layer. Since the inhibitors prevent the deposition of the corrosion products on the coupon, they may also function by dispersing the agglomerated insoluble corrosion products into colloidal particles thixotropically. Streicher has vaguely proposed that gelatin inhibits the corrosion by retarding the evolution of hydrogen at the precipitate which is formed on the surface[8].

It appears that the corrosion of aluminum in sodium hydroxide solutions is under mixed control, with emphasis on the cathodic reaction. When dextrin is used as an inhibitor the corrosion process is again under mixed control but with predominance of inhibitor action on the anodic areas. In acid medium, on the other hand, the corrosion process is found to be essentially under cathodic control[17].

Acknowledgment

The authors thank Prof. M. R. A. Rao for his keen interest in this work.

References

1. M. A. Streicher. *Trans. Electrochem. Soc.*, 93, 285 (1948).
2. M. A. Streicher. *Ibid.*, 96, 170 (1949).
3. M. E. Straumanis and N. Brakss. *Ibid.*, 95, 98 (1949).
4. M. E. Straumanis and N. Brakss. *Ibid.*, 96, 310 (1949).
5. A. B. McKee and R. H. Brown. *Corrosion*, 3, 595 (1947).
6. J. V. Petrocelli. *J. Electrochem. Soc.*, 99, 513 (1952).
7. G. G. Eldredge and R. B. Mears. *Ind. and Eng. Chem.*, 37, 736 (1945).
8. M. A. Streicher. *Ibid.*, 41, 818 (1949).
9. G. T. Colegate, *Metallurgia*, 39, 316 (1949).
10. M. Brooke. *Chem. Engg.*, 59, No. 9, 286 (1952).
11. J. Sundararajan and T. L. Rama Char. *Corrosion Prevention and Control*, 5, No. 5, 55 (1958).
12. J. Sundararajan and T. L. Rama Char. *Ibid.*, 6, No. 1, 41 (1959).
13. J. Sundararajan and T. L. Rama Char. *J. Sci. and Ind. Res.*, 17B, 387 (1958).
14. J. Sundararajan and T. L. Rama Char. *Bull. India Section, Electrochem. Soc.*, 8, 35 (1959).
15. T. L. Rama Char and J. Sundararajan. *Chemical Age of India*, 10, No. 4, 503 (1959).
16. J. Sundararajan and T. L. Rama Char. *J. Sci. and Ind. Res.*, 18B, 496 (1959).
17. J. Sundararajan and T. L. Rama Char. *Ibid.*, 18B, 539 (1959).
18. J. Sundararajan and T. L. Rama Char. Unpublished work.
19. P. N. Aziz and H. P. Godard. *Ind. and Eng. Chem.*, 44, 1791 (1952).
20. W. Katz. *Metalloberflache*, 11, No. 5, 145 (1957).
21. H. H. Uhlig (Editor). The Corrosion Handbook, John Wiley and Sons Inc., New York, p. 41 (1948).
22. N. Hackerman and J. D. Sudbury. *Trans. Electrochem. Soc.*, 93, 191 (1948).
23. H. H. Uhlig. *Annals of the New York Academy of Sciences*, 58, Art. 6, 843 (1954).
24. R. H. Brown and R. B. Mears. *Trans. Electrochem. Soc.*, 74, 495 (1938).
25. M. Stern. *Corrosion*, 14, 440t (1958).
26. M. A. Rakuzin. *J. Russian Phys. Chem.*, 53, 357 (1921).
27. S. Yamaguchi. *Kolloid Zeitschrift*, 126. Heft 2-3, 155 (1952).

Any discussion of this article not published above will appear in June, 1961 issue.

Methods and Experience in Underground Cathodic Protection*

Part 1—Lead Sheathed Communication Cables

By OLIVER HENDERSON

Abstract

An account is given of various methods used by a telephone company to minimize the corrosion of lead sheathed underground communication cables. Controlled drainage connections were established into all d-c railway substations, forced drainage systems set up to overcome end effects and use made of rectifiers, magnesium anodes and magnesium ribbon to overcome anodic conditions.

Utility structures were consistently isolated from each other. Insulation joints were used at building entrances, resistance bonds were avoided at pipe line crossings and insulators used in anchor guys. But the advantages of isolation will soon need reconsideration in view of the growing tendency to interconnect telephone cable sheaths and power company multi-grounded neutral system. 5.2.1, 7.7, 8.2.1

About the Author

OLIVER HENDERSON is Foreign Wire Relations Engineer for The Ohio Bell Telephone Company, Cleveland. His work includes coordination of structural, inductive, protection and electrolysis analysis problems involving telephone company plant and that of other utilities. A graduate from Case Institute of Technology (1922) with a BSEE, he obtained his EE degree from Case for his work on carrier telephone systems on cable conductors. He has worked for Ohio Bell since graduation and is a member of the Cleveland Committee on Electrolysis, composed of 18 major utilities in northern Ohio.

Nature of the Problem

THE GENERAL corrosion problem in the vicinity of Cleveland is somewhat peculiar to the locale in that the area still has electric railway trains and electric trolley buses. There is also an abnormally high concentration of large pipe lines feeding the oil refineries, most of which lines are cathodically protected.

The use of controlled drainage into railway substations is the obvious solution to the stray railway current problem wherever practicable. This procedure is feasible only near the substations, which fact limits its use to the core areas of the city. It follows that some other type of protection must be employed in fringe areas where the so-called "end effects" occur. In such areas, the telephone company uses cathodic protection only as a last resort. Many problems can be corrected by plant rearrangements, addition of ties, bonds, insulating joints or similar means before cathodic control need be considered. Thus, as far as possible, only maintenance money is spent and only passive equipment requiring little or no subsequent maintenance effort is added.

There will remain, of course, a certain few anodic locations for which cathodic protection is the only feasible solution. These cathodic installations are engineered for the minimum adequate amount of current, both in the interest of economy and to prevent interference with the corrosion problems of other nearby underground utilities. All three common types of cathodic protection, (i.e., rectifiers, magnesium anodes and magnesium ribbon) have been used or tried.

The "end effects" mentioned previously are stray currents from the outer ends of electric railway or trolley bus systems. Such currents cannot be effectively drained to the central railway substations because of their remote locations. Due to the relatively large amount of direct current involved, the solution may resolve itself into cathodic protection by the use of a rectifier. Because the underground lines of at least two utilities are usually similarly anodic at the critical spot, it is often possible to work out a joint use plan whereby the communication company furnishes the rectifier and the power company furnishes the alternating current supply.

Example of Use of Rectifiers

Along the Cleveland lake front an end effect situation formerly existed at which the currents leaving the cable varied radically with the fluctuating traction load. These stray earth currents were damaging telephone and municipal power cables and were threatening high pressure water mains.

A controlled rectifier using a magnetic amplifier was designed and built for the location. The entire installation is discussed in detail in an article by the author.[1] The rectifier in this case was used for forced drainage rather than for the conventional concept of cathodic protection. When properly adjusted, the output of the rectifier increased or decreased automatically so that at each instant the amount of drainage was adequate to protect the underground cables but was not in excess of the value at which the water mains would become anodic. This system has been in continuous successful operation without maintenance troubles since 1952.

Example of Use of Magnesium Anodes

Near the Cleveland Hopkins Airport the underground telephone cables were anodic, a situation that came about largely because of stray current generated in that vicinity. This seemed somehow to be aggravated by the rather swampy subsoil and a high water table.

Because of the extreme importance of the many special airport services in the telephone cables it was necessary to take special precautions to correct the anodic conditions. Insulating joints were cut into the lead sheath cables at a point about one mile from the airport so as to minimize the current required for cathodic protection.

About forty 32-pound magnesium anodes were then installed along this route. The telephone conduit run averaged about 600 feet between manholes. Four anodes were buried in each 600-foot section at points about five feet to each side of the duct run. The anodes were connected to the cable sheaths at the adjacent manholes.

The anodes successfully corrected the anodic condition. However, subsequent extensive road work on the approaches to the airport resulted in the destruction of several anode installations. In one instance, a field engineer arrived just in time to see an earth mover scoop up two anodes, as evidenced by the two wire leads dangling from the shovel. As a consequence electrical current measurements were made at each anode each week during the period of high road activity. This has now been reduced to a monthly check.

The lead sheathed cables in this run are gradually being replaced with polyethylene sheathed cables. For this reason, all anode replacements are now made with the smaller 17-pound units having a shorter life that is more consistent with the ultimate life of the last of the lead cables.

Attempted Use of Magnesium Ribbon

Several years ago an experimental installation was made using a magnesium ribbon with a cross-section of about ½ x 1 inch, which could be pulled into a vacant underground conduit duct to protect the lead sheathed cables in the same run. The ease of installation made it look attractive but the protection proved to be short lived. The conductivity of the ribbon to earth was concentrated at the joints in the 3-foot sections of the tile conduit. As a result the magnesium ribbon disappeared rapidly for a few inches at each tile joint leaving the rest of the ribbon unexpended and ineffective. Moving the entire ribbon a few inches each month overcame the trouble but put the entire procedure in the nuisance class.

General

To date cathodic protection has been applied to the cables without aggravating the corrosion problems of any other utility. In one instance, however, the protection applied to a pipe line created a problem on the cable. The situation was corrected by digging up the buried cable

*Submitted for publication September 11, 1959. These three papers were given at a panel discussion at the Cathodic Protection Symposium, North Central Regional Meeting of NACE, Cleveland, Ohio, Oct. 22, 1959.

and wrapping it with insulating material for a distance of 50 feet on either side of the involved crossing. This procedure stopped the exchange of current between the cable and the pipe line and avoided the use of a resistance bond.

In another instance, a rectifier caused excessive noise in a nearby private branch exchange telephone switchboard. This noise was eliminated by placing a suitable filter in the rectifier output. It appears that filters should be placed in all such rectifiers in areas where telephone services exist.

Stray current from the d-c traction system is still a dominant factor in the Cleveland area. It is a practice to isolate underground cable plant from other underground structures such as power cables, water and gas lines. As a result, cathodic protection installations are able to move the plant electrically in the negative potential direction with less current than would otherwise be required if all underground structures were interconnected. Isolation, however, demands insulating joints in all cables entering buildings and does not permit the use of resistance bonds to other utility structures except d-c substation drainage.

Summary

Because of the high maintenance and eternal surveillance demanded by all forms of cathodic protection the local telephone company has limited use of this measure to only a relatively few low current situations and only where other mitigative measures are impracticable. However, with the exception of the magnesium ribbon experiment, each installation has achieved the desired protection for which it was designed.

The author has seen corrosion control grow from a crude cut-and-try gesture to a far more intelligent engineering procedure. Especially in the realm of the design of cathodic protection should the need for adequate pretesting and theoretical computation precede the design and selection of the rectifiers or anodes. For example, "reduction tests," whereby storage batteries are employed instead of a rectifier on an advance experimental basis, are time consuming but if carefully conducted and interpreted can be made to yield information that can guarantee the success of the permanent installation.

Reference

1. Magnetic Amplifier Controls for Rectifier Protecting Underground Metallic Structures Cathodically. *Corrosion* 9, 216 (1953) July.

Part 2—Bare Steel Pipe Lines

By L. H. WEST

Abstract

A discussion is given of survey methods used for the detection of galvanic "hot spots" along bare steel pipe lines, correlation of these data with actual failures, and galvanic anode installation. Results of the survey correlated well with corrosion leak experience and with visual inspection of the pipe lines. Two case histories are reported. 3.6.6

THE BARE portion of a products pipe line system operated by Sohio in Ohio consists of approximately 300 miles of 4 inch to 8 inch welded steel pipe. This pipe, laid in the period 1938-42, is now under cathodic protection. Thirty-two percent of its length is protected with magnesium anodes and the remainder with rectifiers. The discussion here will be concerned with the surveys, designs, and results of work with the galvanic anodes in non-stray current areas.

Magnesium anodes have been placed at anodic "hot spots" located by pipe to soil potential surveys. This approach was investigated in preference to the soil resistance analysis used by many corrosion engineers for the following reasons:

1. One 38-mile section of bare 6-inch pipe presented a serious corrosion problem. This line was laid in 1938-39, and is buried in soil of 3,000 ohm-cm and lower resistivity for 75 percent of its length. Very little variation in soil resistance could be seen along much of this right-of-way.

2. Another twenty-mile section of used 6-inch pipe was laid in 1942. Some of this pipe was manufactured from wrought steel as long ago as 1910. Soil resistivities along 70 percent of this right-of-way range from 10,000 to 550,000 ohm-cm. Many of the earliest corrosion failures were experienced in the highest resistance soils, often assumed to be non-corrosive. Also, frequently the leaks did not coincide with "breaks" in the soil resistance profile.

Seven years of experience with the pipe-to-soil potential survey and cathodic protection based on its results are reported here.

Survey Methods

The surveys used in locating galvanic "hot spots" depend upon the interpretation of potential measurements taken between the pipe line and the soil at various selected points. Some observations are actually taken between two points on the surface of the earth, but finally these are always viewed with respect to the pipe itself. It is assumed that the potentials discussed here are made up of both back EMF and IR loss, as no corrective bridge circuit has been used. All potential measurements to be mentioned have been made with a simple potentiometer, and copper-copper sulfate half cell for soil contact. They are plotted and analyzed with respect to each other for the purpose of determining the direction currents tend to flow with respect to the buried structure.

The first work was done by plotting pipe to soil potential, as read with the electrode placed directly over the pipe, against distance. The pipe line itself was contacted only at 500-foot intervals. Successive soil to soil potentials, also read over the pipe, were then algebraically added to the original (See Figure 1). Assuming current flow from plus to minus, its direction between two soil contact points was also shown on the plot.

This so-called "surface potential" form of measurement has several features which limit its practical usage:

1. The algebraic addition of soil to soil readings to the original pipe to soil voltage is time consuming and can be a source of error.

2. Any mistake in recording the polarity of a soil to soil voltage can mean a portion of the survey to re-run.

3. Field instruments often do not give a significant reading unless the spacing between soil contacts is in the neighborhood of 100 feet. This means also that many smaller, but more concentrated, anodic areas along a line could be overlooked.

Because of these disadvantages, which were magnified by the fact that the persons available for the field survey work have little or no technical background, the "pipe to soil" survey variation schematically illustrated by Figure 2 was adopted. As can be seen, this involves simply the measurement of pipe to soil potential. The observer reads his instrument and records the reading without constantly noting the polarity of each value. Readings with the soil contact to the side of the pipe line are also taken at frequent intervals. With a little experience, the instrument man can immediately detect an anodic section while he is still in the field.

The normal practice has been to take pipe to soil potential readings at 25 foot intervals over the pipe line. Side readings, approximately 10 feet away from the line, are noted often enough to ascertain the direction of potential away from or toward the pipe, and perpendicular to its axis. A 300 foot cord was found to be the most practical length. This means that 600 feet of pipe can be checked without moving the potentiometer. A longer cord becomes unwieldly in brush and heavy weeds, while a shorter one would require excessive moves. An insulated, nylon reinforced cable is used.

One cause for difference between a

About the Author

LEWIS H. WEST is Corrosion Engineer of the Products Pipe Line Division, The Standard Oil Company of Ohio. He has been engaged in pipe line corrosion control work for past 12 years and is a member of several technical practices committees. He is graduate of Cornell University, Mechanical Engineering. Mr. West is a registered professional engineer in the states of Ohio, Pennsylvania, Michigan and Indiana.

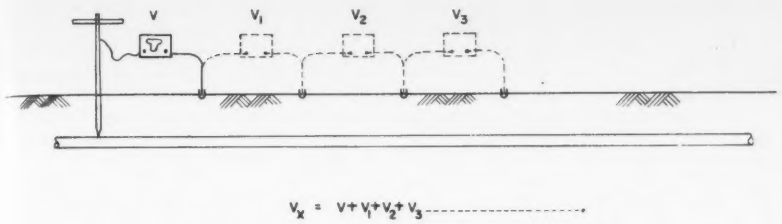


Figure 1—"Surface potential" survey employing two soil contacts.

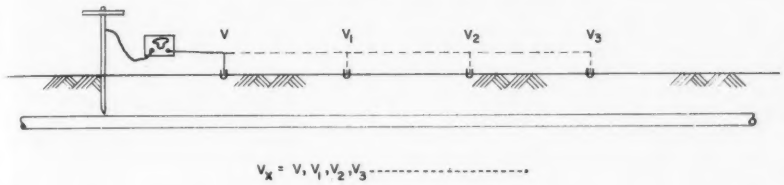


Figure 2—Pipe to soil voltage survey.

pipe to soil reading with soil contact immediately adjacent to the pipe contact and another several hundred feet away (along the pipe's axis) is the IR drop due to current flowing in the pipe. This is usually negligible in non-stray current areas. However, even an appreciable amount of current flowing steadily should have little effect upon the relative values of successive pipe to soil potential readings which, after all, is the primary interest. The 300 foot cord is calibrated and marked so as to be used also as a chain.

Simultaneously, soil resistance readings are taken to the side of the pipe line. The four pin or "Wenner" method is used, with pins spaced 5 feet apart. This data is taken every 100 feet and at "hot spots" or anodic areas located by the pipe to soil potential survey. Soil resistance data is used as a guide in the design of galvanic anode installations, and "double check" on the pipe to soil potential survey. Experience indicates that sharp differences in consecutive soil resistance readings are usually coincident with anodic sections of pipe located through pipe to soil potential measurements and actual failure occurrence. However, the converse is not necessarily true.

All data are recorded on the specially printed forms shown in Figure 3. These are supplied in pads and punched for filing in pocket size, loose-leaf field notebooks. A distance from any land mark to the nearest reading, as measured along the axis of the pipe, is always recorded on the data sheet line below that reading. Swamps, woods, ravines, or any other irregularities along the right-of-way are noted. A pipe to soil potential reading, taken with the copper-copper sulfate half cell placed over the pipe is recorded in the Vg column. The potential, taken after the cell is moved to the side is recorded as an exponent of the "over the pipe" potential.

Analysis of Data

Both pipe to soil potential and soil resistance data are plotted along the ordinate, while distance is the abscissa.* A sample section of one of these "profile sheets" is shown in Figure 4. Also plotted with these are the location of all fences, property lines, roads, railroads, or any other landmarks, which could be used for future reference when relocating a particular spot or installing anodes. After recording information in this manner, all original field data sheets are placed in an office card file.

All locations where pipe to soil potential are greater when the contact is placed over the pipe than when it is placed along the side are considered to be "anodic" areas or "hot spots," and are designated by the symbol X on the graph and data sheets. (Potentiometer connected with its positive terminal to the copper-copper sulfate half cell.) When dictated by instrument accuracy, a side potential reading equal to an over-the-pipe one can also be considered critical.

Soil redox potential measurements were not taken in conjunction with any of these surveys. However, the results of such readings would be interesting to correlate and could possibly be used in the evaluation.

Magnesium anodes are laid out and installed along all sections of line considered to be discharging current. The number of anodes used at a particular location, their spacing, and size is based on soil resistance data and length of the anodic "hot spot." Either 9 lb or 17 lb packaged, standard alloy anodes are buried vertically, on alternate sides of the pipe lines at center-to-center distances which vary from five feet to thirty feet. The minimum number of magnesium anodes in a particular group is four. This results usually in 150 to 200 anodes per mile of 6 inch or 8 inch bare pipe.

Evaluation and Results

In 1955, 80 miles of unprotected bare pipe which had experienced only 4 or 5 corrosion leaks was surveyed. Before the protection program was completed in 1958, 72 corrosion failures had occurred.

*A plot of the log of resistivity might be somewhat more convenient to analyze. However, it was felt that the value of such a curve is outweighed by the combination profile which shows all data on one sheet (pipe to soil potential, soil resistance, and sometimes current flow), and that combined coordinates could be confusing.

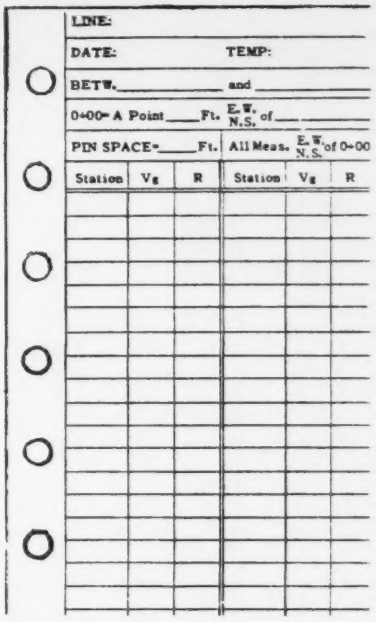


Figure 3—Form used in the field to record soil resistance and pipe to soil voltage readings.

In approximately 95 percent of the cases, their locations coincided with anodic "hot spots" located by the surveys.

Analysis of this type of information has indicated that the test data show only those sections which tend to corrode. It has not been possible to determine the relative severity of the different locations from the readings. This is, of course, probably due to variation in soils and distance between the soil contact and strongest part of the anodic area.

The survey results have also been useful for line repair work in the vicinity of corrosion leaks. Here, it serves as a guide for estimating the amount of pipe to be reconditioned, and again, actual pipe condition has correlated well with survey data.

Magnesium anodes which have been installed in the higher resistance soils have outputs which, in many cases, are less than ten milliamperes. However, they are very effective in lowering pipe to soil potential sufficiently (0.25 to 0.30 volts). Examples of protection effectiveness can best be illustrated by citing examples:

1. The 20-mile section of 6 inch line, mentioned earlier, contains some pipe which is fifty years old. Twelve miles of it have been protected with magnesium anodes. Today the entire section is operating with a leak rate of one or two per year. At one time, it had been experiencing five to six times as many in the same period of time. A total of only 3,000 ft. (±) has ever been replaced.

2. The other 38-mile line had magnesium anodes connected to it in 1952. This installation was based on the "surface potential" type survey using two soil contacts. In 1955, a 10 inch loop line was installed on the same right-of-way, disconnecting some of the anodes. There-

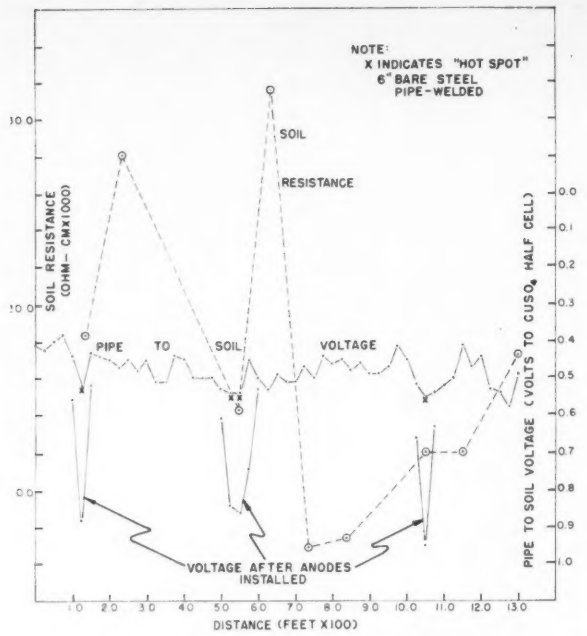


Figure 4—Pipe to soil voltage and soil resistance vs distance

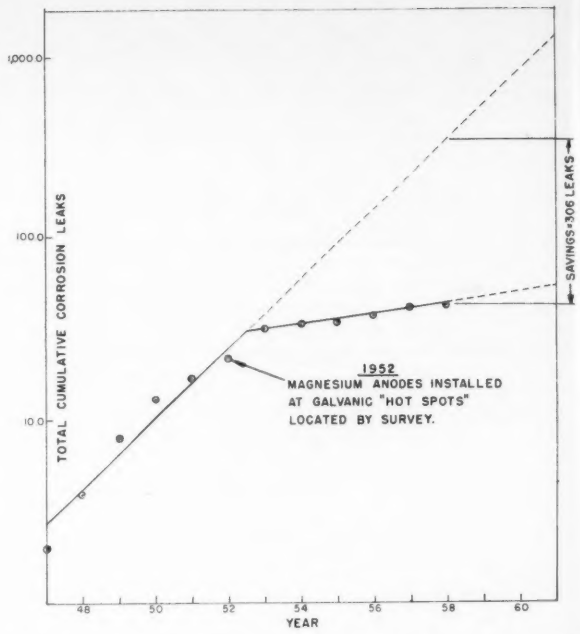


Figure 5—Total corrosion leaks vs time for 37.35 miles of 6-inch bare welded steel pipe.

fore, the line was re-surveyed, anodes were replaced, and some rectifiers added in 1957-58.

Figure 5 is a leak expectancy curve plotted for this pipe line. As can be seen, the plot "breaks" sharply after 1953, and a savings of 306 corrosion leaks between the actual and theoretical projected curve is shown. It is also interesting to note that it was not until two years after the cathodic protection had been installed (1954) that a significant change in the slope of the curve was seen. The period of time was found to be practically the same in all similar cases. No more than 2,000 feet of this pipe line has ever been replaced.

Several discrepancies in the discussed method of protection are fairly obvious:

1. Changing conditions along a pipe line right-of-way can create new galvanic corrosion cells or eliminate those already existing. For example, housing developments mean the construction of roads and septic systems. Pipe line construction, changes in agricultural tile drainage, and highway programs have similar effects.

2. Bacteriological activity is probably not detected by the pipe to soil potential survey. However, this type of attack has been found coincident with many located galvanic "hot spots."

3. Stray current problems require an entirely different approach.

For these reasons, and also because magnesium anodes are always subject to damage from construction work, it seems best to limit the type of cathodic protection mentioned here to those lines which lie in fairly open country, and where occasional leakage can be tolerated.

Summary and Conclusions

Pipe to soil potential measurements have been used for several years to locate galvanic "hot spots." Results of the surveys have correlated well with corrosion leak experience and visual inspection of the pipe lines. Over-all results of cathodic protection applied on this basis have been satisfactory as can be seen from the specific examples which have been cited. Long term effectiveness of the galvanic anode system described might be considered somewhat nebulous. However, it should be at least as good as any based on soil resistivity alone. The use of galvanic anodes as described should always be considered applicable only after careful consideration of its limitations.

Part 3—Gas Transmission and Distribution Lines

By P. P. SKULE

Abstract

A general coverage is made of cathodically protecting gas services, distribution, transmission and storage lines for new and existing older lines. Benefits and weakness in protection methods are discussed. Early day protection of lines is contrasted with present methods. 8.4.2

THIS PORTION of the report will contain general observations and experiences in mitigating underground corrosion on part of the 10,000 miles of pipelines operated by The East Ohio Gas Company within the State of Ohio. Served are some 800,000 consumers in 175 communities. The line includes 1,500 miles of transmission facilities, and 700 miles of storage and production lines to 900 gas wells; the remaining 7,800 miles consists of distribution lines.

Company operating experience for over a half of a century indicates that substantial progress has been made against corrosion in recent years but that changing conditions and circumstances show that there still is much to be desired.

One great economic problem facing the industry is the necessity for replacing early corroded distribution lines with substantially the same diameter pipe. Present cost of labor and material has so skyrocketed that new economic avenues of approach to this problem must be found. These low pressure line replacements do not serve to increase the number of consumers, nor do they carry more gas. But they do represent a major maintenance expense.

At the turn of the century when initial construction took place, most lines were constructed of thick walled bare unprotected, soft steel or wrought iron pipe joined together with couplings. Experience has shown that these early lines generally provided exceptionally long trouble free operating life. Parts of these lines are still in service. A beneficial co-incidental set of circumstances largely contributed to this longevity. Soft steels and wrought iron metal appear to have been corrosion resistant and the thick walled pipe gives longer life. Today pipe is of the hard thin walled steel type which is capable of carrying higher pressures but seems also to be much more vulnerable to corrosion. Corrosion rate for hard steel seems greater and de-icing salt environment is severe on this pipe.

Couplings served to break up long line currents acting as high resistance joints, thus greatly reducing galvanic and stray

current effects. Welded pipe lines are continuous conductors.

Early line pressures were low; the most significant item producing long life was the extensive undisturbed and non-contaminated good loam, clay and sandy soils that existed in many areas traversed at that time. Early lines were laid rather shallow and followed land contours. Later, however, huge earth moving equipment was used to level off ground so that lines were laid in substrata and mixed soils.

In the middle and late twenties another spurt of expansion took place wherein distribution lines were extended into suburban areas where heavy wet clay soils predominate.

Some form of pipe protection was required because of the changing characteristics of the soil and the higher pressures needed to force gas longer distances. So coated pipe was installed without cathodic protection. Commercial galvanic anodes at that time were then largely unknown.

On the whole, these early coated lines performed adequately. Nevertheless coating holidays led to premature nuisance repairs in some instances.

By 1940, the international situation caused such economic disruption that any pipe became difficult to obtain, particularly coated pipe. Throughout the duration of the war, bare pipe was installed. Sand fill required by cities was thought to act as a substitute for coating.

It might be pointed out also that war restrictions put a freeze on availability of zinc anodes which had been used infrequently prior to 1940.

Shortly after the end of World War II, the company instituted a policy of installing only coated and cathodically protected lines. Magnesium anodes were installed.

Expansion during the past six years has required the installation of 600 to 800 miles of pipe per year, ranging from 2 inches to 30 inches in size. As many as 17 contractors work in the Cleveland area daily. Production line techniques must be followed for anode requirements with the least amount of engineering. Despite the coating and cathodic protection installed, mechanical problems still exist.

On large transmission lines, extensive rock trench, casings and numerous line crossings presents obstacles in the obtaining of proper cathodic protection. Pipe insulated from well sealed casings cannot be cathodically protected. Rock impedes the flow of cathodic current to the pipe, and dense line crossings often prevent desired spacing of rectifiers even on coated lines.

Wherever possible, inexpensively installed magnesium anodes are used initially to protect new coated transmission lines and also to avoid cathodic interference. Interference is a major problem in Ohio which is a crossroad for pipe lines.

Surprisingly, about three-17 lb. magnesium anodes installed per mile on a 30-inch coated pipe line has resulted in efficient current distribution and protection. One 30-inch line averages 120 milliamperes of current per mile of pipe. Lately, the anodes have been installed so they can be easily disconnected if foreign interference currents disrupt the magnesium anode system.

Other lines in highly aerated high resistant soils or in rock trench often require impressed current systems. But low resistant wet clay soils present very few problems if quality of coating is average.

An attempt to cathodically protect hot spots in older bare transmission lines with galvanic anodes has been tried. This did not prove successful in severely corrosive soils, but one 19 year old experimental zinc anode installation did show encouraging results for lesser pressured lines situated in average soils.

Today's large diameter high pressure transmission line operation practically bars piece meal attempts to cathodically protect bare lines with anodes. It is difficult even to protect them fully with impressed current systems.

Among obstacles that exist in securing cathodic protection of large diameter bare transmission line, mention might be made of (1) road improvements, (2) coal mine drains, (3) coal and coal blossom, and (4) ditches polluted with de-icing salt and mine water surrounding growing industrial and residential suburban areas containing distribution line crossings.

Lines to storage wells from compressors involve, in addition to the above obstacles, the problem of heat of compression extending for miles around stations. Though the gas is partially cooled, it can interfere with cathodic protection mechanism even when coated with high temperature resistant enamels. Heat appears to drive off the polarization effect.

Service lines have been insulated at the main for more than a quarter of a century. For a lesser number of years all new services also have been insulated at the meter to protect the consumer's service against galvanic corrosion caused by copper water services.

Gas distribution mains are the most extensive and the most complex system to cathodically protect.

All new distribution construction embodies mill coated pipe and galvanic anodes but this is just a beginning. New lines are often extensions of or are replacements of older non-protected lines which must be insulated at the tie-in points. These new lines have many service line connections which also must be thoroughly insulated from the mains.

The problem of properly field coating service line connections, pipeline welds, couplings and other fittings is still a wide open question. Contacts to other gas and water services and mains is a constant threat to cathodic protection. Even curb box contacts rob the main of cathodic current so insulating gaskets had to be developed.

Electric railway and mine equipment stray current is still a problem in some areas. Insulating joints, drains and rectifiers are used to combat this problem.

Maintenance of older existing distribution lines, bare or coated, but not cathodically protected presents even greater problems than does new construction.

Because so little thought was given to cathodic protection years ago, insulation at terminals, contacts and non-bonded couplings, many of which are under walk and paving, it is impractical in many cases even to obtain static pipe potentials or soil resistances. On top of this, the distribution system is plagued by suburban septic tank affluent, by city steam lines, and by de-icing salts on streets and by other contractors working across or parallel to gas lines which ruins coating, knocks off anodes and creates additional contacts.

Large diameter older non-protected existing distribution feeder lines, especially the coated type, are selected yearly for a program wherein anodes are added to the many single random length coupled pipe joints. This program is over ten years old and results are exceedingly gratifying even though cost is more than a dollar per foot of line protected. Up to ten miles of pipe per year are equipped with galvanic anodes, primarily under walk, paving and well sodded tree lawns.

Older existing low pressure distribution lines are similarly treated but the problem of insulating from other mains and the occurrence of accidentally shorted services puts a serious economic crimp upon this program.

The author believes that in the next few years revolutionary new coating practices and line replacement methods will take place. Even now, besides the tars, asphalts and waxes, such materials as extruded plastic, plastic tape and epoxy tar resins are available. It is predicted that replacement procedures probably will consist simply of leak-proofing existing pipe in place for the low and intermediate systems.

In summarizing, it is evident that corrosion engineers have a great opportunity to pioneer into new allied fields and that they will not be content with just cathodic protection alone. Other mechanical means can and will be developed which will add new tools to meet new conditions. And this will result in economic gains for gas distribution companies.

About the Author

PETER P. SKULE is Chief Corrosion Engineer in staff for The East Ohio Gas Company, Cleveland Ohio. He has a BS degree in Mechanical Engineering from Case Institute of Technology, Cleveland, Ohio. He also holds a LLB degree, is a member of the Ohio Bar and is a registered engineer in the state of Ohio. For nearly two decades he has worked entirely on gas pipe line corrosion problems including services, distribution, transmission and storage lines. He is an active member of NACE, now Secretary of the Cleveland Chapter, and the Cleveland Engineering Society.

Design for Prevention of Pipe Line Corrosion Based on Survey of Ground Potential Distribution*

By SHIGEO FUKUTA,(1) SHIN-ICHI KONDO,(1) NOBUO USAMI(2) and SHIGEKI SEKIMOTO(3)

Abstract

This is a report of a procedure adopted in designing the cathodic protection system and other corrosion control provisions for a pipe line. The steps taken were as follows: (1) pipeline route was determined; (2) ground potentials along the route with reference to a fixed sufficiently remote ground potential were measured with recording instruments, and ground potential distribution profile of the route was obtained; (3) pipe-to-ground potential distribution along the route was anticipated according to the above cited ground potential distribution profile; (4) specifications for the pipe protective coating and covering, locations of cathodic protection or drainage equipments and their current ratings were determined; (5) pipes and other necessary materials were prepared and installed; (6) after the pipe line construction work was completed the pipe-to-ground potential distribution profile was obtained to check the adequacy of the design. Thus the adequacy of the design was confirmed. 8.9.3, 5.11

Introduction

THIS IS a report of the procedures adopted to provide the necessary protective coverings and cathodic protection for a 10.6 mile gas pipe line installed in 1956 across the downtown district of Nagoya City by the Toho Gas Company. Attention was given also to the results of a survey carried out after the burial of pipe line was completed to check the adequacy of those procedures.

It is interesting to note that it was the preliminary survey of ground potential distribution along the planned pipe line route using a suitably remote reference ground electrode that supplied the most useful basis for pipe line corrosion control design.

The pipe line route is shown in Figure 1. Table 1 shows the protective coverings used on this steel pipe.

Preliminary Survey of Ground Potential Distribution

In order to determine the specifications for pipe coating and the location of cathodic protection equipment required, it was decided to survey the ground potential distribution along the route planned by the company, utilizing a remote reference ground electrode.

The copper plate station ground electrode at Tazimi Telephone Central Office, situated 25 miles northeast of Nagoya City, was used for reference potential. Tazimi is so remote from the urban district and electrified railroads that the ground potential there was assumed to be practically neutral.

Another problem lay in preparation of necessary pilot wires connecting the reference ground electrode at Tazimi and probe ground electrodes in the pipe line route in Nagoya City. Here again by courtesy of the Nippon Telegraph and Telephone Public Corporation, spare telephone conductors between Tazimi and Nagoya City were authorized for use as the necessary pilot wires.

Figure 2 shows the measurement of stray current IR drop along the pipe line right-of-way before the pipeline was buried. The data in Figure 4 were obtained with this arrangement.

Figure 3 shows the measurement of the pipe-to-ground potential difference at each point. This arrangement was used in obtaining the data given in Figures 5, 6 and 7.

Copper sulfate half cells were used, connected as shown in Figures 2 and 3, as probe electrodes for the ground potential survey.

Potentials at four consecutively neighboring locations were recorded simultaneously for 30 minutes by means of a multi-element recorder, mean values of the recorded ground potentials at respective locations being enumerated and presented in Figure 4.

Ground potential at any location was of highly variable character due to stray ground currents from various sources; thus it was necessary to use its mean value of the recorded duration for presentation in ground potential profiles.

The ground potential profile in Figure 4 clearly shows that the ground potentials of the left half zone of the route are positive and those of the right half zone are negative. Hence if a sufficiently long pipe line is buried along this route, the left half of pipe line will be cathodic and the right half anodic. Thus, from the corrosion point of view, the latter zone will be dangerous while the former zone will be safe.

Design of Corrosion Preventive Installations

From the results of the ground potential distribution survey described above,

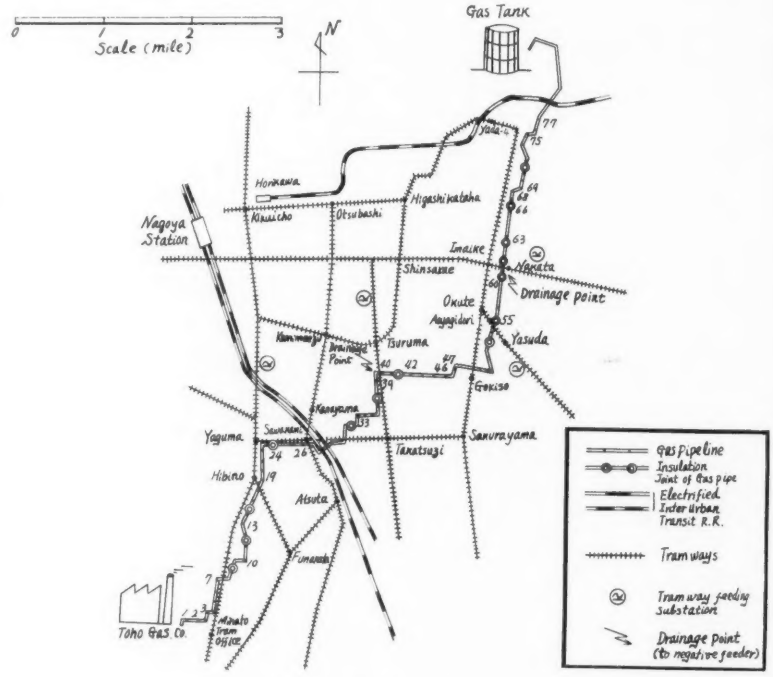


Figure 1—Pipe line route map.

★ Submitted for publication September 1, 1959.

(1) Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya City, Japan.

(2) Tokai Telecommunication Bureau, Nippon Telegraph and Telephone Public Corp., 3 Komehama-cho, Naka-ku, Nagoya City, Japan.

(3) Toho Gas Co., Sakurada-cho, Atsuta-ku, Nagoya City, Japan.

it was decided to provide the pipe line in the left half zone with protective coverings of higher leakage resistance. This would limit the current flowing into the pipe line and limit, in effect, the current leaving the pipe line in the dangerous zone.

The pipe line in the dangerous zone was provided with protective coverings of lower leakage resistance to save expense, and was further equipped with cathodic protection at two selected locations (at points No. 39 and No. 60 in Figure 1).

The cathodic protection means drainage connection of the pipe line through a selective drainage rectifier and resistor to a nearby negative feeder of the municipal tramway system. The kind of pipe protective covering and the mean insulation resistance per unit length is given in Table 1. Surveys were made after the pipe line construction was completed.

Various surveys were carried out after the construction work was completed as described below:

At first the pipe-to-ground potential distribution along the total route was measured by using saturated copper sulfate half cells and voltmeter (Type: Standard No. 2). The results are shown in Figures 5 and 6. Data in Figures 5 and 6 were obtained under the condition in which all insulation joints of gas pipe were connected by conductors.

As the pipe-to-ground potential reading with a copper sulfate half cell should be about —0.8* volt for protection, the potential values of pipe line should be lower than the line 0'0''. (See Figure 5).

The pipe line apparently is being cathodically protected by stray currents from terminal No. 1 to terminal No. 26, and being corroded between terminals No. 26 and No. 75 by stray current discharge. It is clear that the zone between the terminal No. 1 and No. 26 is safe and the rest is dangerous (with respect to corrosion). This coincides very well with the preliminary survey.

Drainage connections were made at two locations, (i.e., lead terminal No. 39 and No. 60.) Figure 6 shows how the drainage effectively works. Curve No. 2 and No. 3 are results of selective stray current drainage obtained by separate resistors. The leakage resistance of the pipe protective coating was measured at 15 subdivided pipe line sections and the average values are presented in Table 1.

Interference With Other Nearby Underground Metallic Structures

Figure 7 shows the result of the investigation of the degree of the interference of the drainage of the gas pipe line with other nearby underground metallic pipes and cables.

For measurement of potential in Figure 7, instruments are connected as in Figure 3.

In Figure 7, potentials to soil of water pipes, telephone cables and power cables nearby gas pipe line are plotted respectively, when drainage current is 0 or 15 Amp. The kinds of reference electrode

* Fe | soil | $CuSO_4$ aq | Cu: about 0.8 v

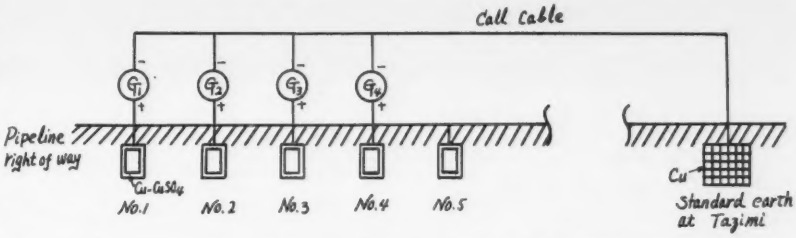


Figure 2—Measurement of ground potential (stray current IR drop) distribution along the pipe line right-of-way.

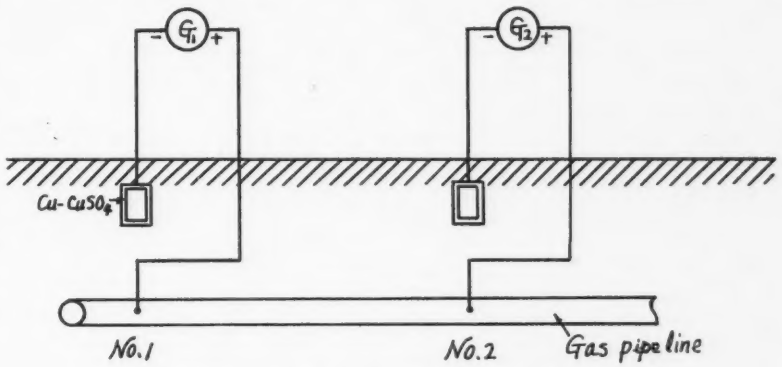


Figure 3—Measurement of the pipe-to-ground potential difference.

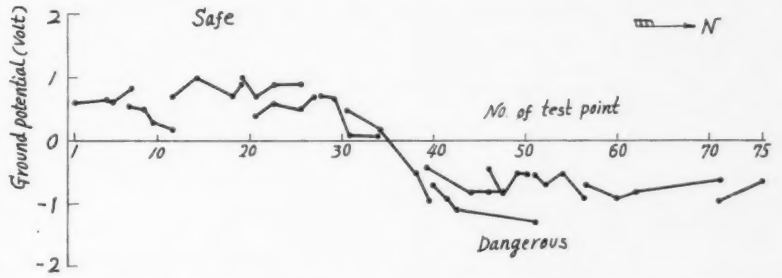


Figure 4—Ground potential (resulting from stray currents) along the planned pipe line route before pipe line is buried.

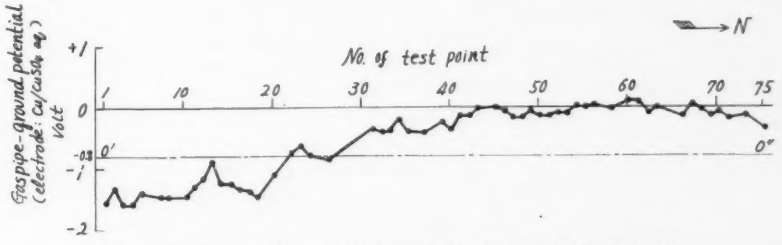


Figure 5—Pipe-to-ground potential (without drainage) after pipe line is buried.

TABLE 1—Pipeline Dimensions, Type of Coating and Coating Leakage Resistance

Area	Length (Miles)	Insulation Method	Leakage Resistance, Ω/Mile			Remarks	
			Mean	Min.	Max.	Dia. (in)	Length (Miles)
No. 1–32....	4.06	Double pitch covering	6.92	5.78	11.76	14 18	1.21 2.85
No. 32–77...	5.31	Single pitch covering	3.16	0.81	6.03	12	
Total area...	9.37	.....	4.41	...	...		

used in this measurement and the marks (1+, 1—, . . .) of curves are as follows:

Remarks on curves	Reference electrode
Curve (1+): Means of positive values of telephone cables	Pb-plate
Curve (1—): Means of negative values of telephone cables	Pb-plate
Curve (2+): Means of positive values of power cables	Pb-plate
Curve (2—): Means of negative values of power cables	Pb-plate
Curve (3+): Means of positive values of water pipe	$Cu/CuSO_4$
Curve (3—): Means of negative values of water pipe	$Cu/CuSO_4$

Potentials are measured by micro-mercury-coulomb meters. Plotted values of water pipe are 0.8 volt smaller than the value read on instrument.

Figure 7 shows that there is very little influence on power cables and telephone cables, and there is some on water pipe. Water pipe is dangerous even if the drainage current of gas pipe line is zero, and the increase of danger by drainage is not so important. It can be seen that the interference is small and that the drainage is permitted without hazardous effects to other installations.

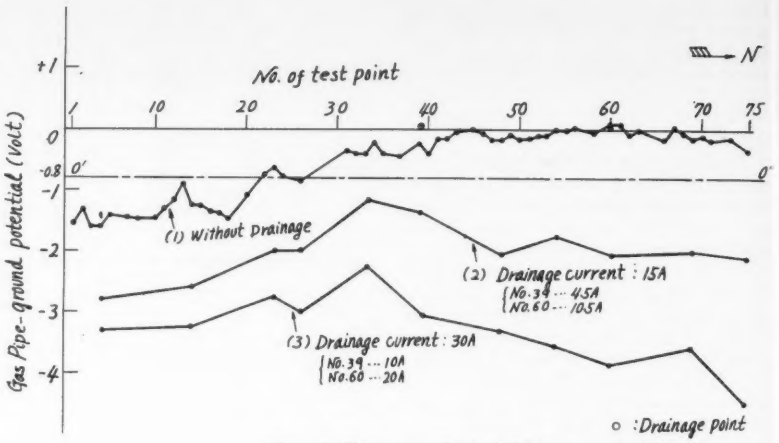


Figure 6—Pipe-to-ground potential (stray currents drained).

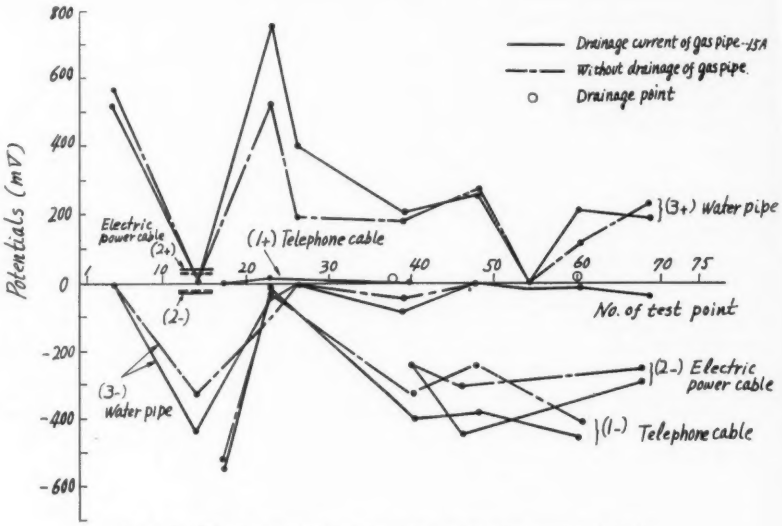


Figure 7—Effects of drainage of gas pipe line on other pipes and cables.

Conclusion

It was confirmed that the location of dangerous zones and the extent of danger can be anticipated by surveying the ground potential distribution along the planned route of pipe line. In this way it is possible to introduce planning in selecting pipe coverings necessary for corrosion prevention and drainage equipments.

Acknowledgment

The authors express their sincere gratitude to Professor Emeritus Okabe, Osaka University, to Professor Tanaka, Osaka City University, and to the Staff of Committee of Study for Electric Corrosion of J. I. E. E. The authors are also indebted to Mr. Maeda and to Mr. Akane, Chief of Supplying Section of Toho Gas Co. for planning of the device and to Mr. Sakai, Chief of Investigation Section of Tokai Tele-Communication Bureau; also to Mr. Hiramatsu of Nagoya Inst. of Tech. and many other friends who helped in this research.

Any discussion of this article not published above will appear in June, 1961 issue.

Directory of NACE Technical Committee Officers

T 1 Corrosion in Oil and Gas Well Equipment

W. C. Koger, Chairman; Cities Service Oil Co., Cities Service Bldg., Bartlesville, Oklahoma

I. A. Caldwell, Vice Chairman; Humble Oil & Refining Co., Box 2180, Houston, Texas

T-1A Corrosion in Oil and Gas Well Equipment, Los Angeles Area

R. L. Davis, Chairman; Superior Oil Co., 900 Palm Ave., South Pasadena, Cal.

T-1B Corrosion in Oil and Gas Well Equipment, Calgary Area

J. U. Messenger, Chairman; Mobil Oil of Canada Ltd., Mobil Oil Bldg., Calgary Alberta, Canada

R. C. Carlson, Vice Chairman; British American Oil Co., Ltd., Box 130, Calgary, Alberta, Canada

T-1C Detection of Corrosion in Oil Field Equipment

J. P. Barrett, Chairman; Pan American Petroleum Corp., Box 591, Tulsa, Okla.

F. A. Prange, Vice Chairman; Phillips Petroleum Corp., Bartlesville, Okla.

T-1C-1 Detecting External Casing Corrosion by Logging Means

H. J. Kipps, Chairman; 10954 S. Kane Ave., Whittier, Cal.

T-1C-2 Use of Probes in Producing Operations

L. K. Gatzke, Chairman; Shell Oil Co., 1700 Broadway, Denver, Colo.

T-1D Control of Oil Field Corrosion by Chemical Treatment

C. C. Nathan, Chairman; Texaco, Inc., Box 425, Bellaire, Texas

T-1E Cathodic Protection of Oil Field Equipment

Jack L. Battle, Chairman; Humble Oil & Refining Co., Humble Div., Box 2180, Houston, Texas

T-1F Metallurgy of Oil Field Equipment

R. L. McGlasson, Chairman; Continental Oil Co., Res. & Dev. Lab., Box 1267, Ponca City, Okla.

T. M. Krebs, Vice Chairman; Babcock & Wilcox Co., Tubular Products Div., 1920 Seventh Ave., Beaver Falls, Pa.

R. S. Ladley, Secretary; Phillips Petroleum Co., Bartlesville, Okla.

T-1F-1 Sucker Rod

W. C. Koger, Chairman; Cities Service Oil Co., Cities Service Bldg., Bartlesville, Okla.

T-1F-2 Tubular Goods

W. F. Oxford, Jr., Chairman; Sun Oil Co., Box 2831, Beaumont, Texas

T-1F-3 Down Hole Pump Materials

F. A. Prange, Chairman; Phillips Petroleum Co., Bartlesville, Okla.

T-1G Protective Coatings and Non-Metallic Materials for Oil Field Use

D. R. Fincher, Chairman; Tidewater Oil Co., 1538 Campbell Road, Houston 24, Texas

G. R. Roberson, Vice Chairman, Standard Oil Co. of Texas, Box 1249, Houston, Texas

T-1G-1 Plastic Coatings for Tubular Goods

A. C. Nestle, Chairman; Texaco, Inc., Box 425, Bellaire 10, Texas

T-1G-2 Cement Linings

R. S. Ladley, Chairman; Phillips Petroleum Co., Bartlesville, Okla.

T-1H Economics of Corrosion Control

R. M. Robinson, Chairman; Continental Oil Co., Box 2197, Houston, Texas

E. J. Simmons, Vice Chairman: Sun Oil Co., Box 2880, Dallas, Texas

T-1H-1 West Coast Area

H. J. Kipps, Chairman; 10954 S. Kane Ave., Whittier, Cal.

T-1H-2 Gulf Coast Area

W. F. Oxford, Jr., Chairman; Sun Oil Co., Box 2831, Beaumont, Texas

T-1H-3 Permian Basin Area

Fair Colvin, Jr., Chairman; 35 Bauman St., Midland, Texas

T-1H-4 Rocky Mountain Area

H. W. Olson, Chairman; Shell Oil Co., 1845 Sherman St., Denver, Colo.

T-1H-5 Midcontinent Area

H. G. Byars, Chairman; Atlantic Refining Co., Box 2819, Dallas, Texas

T 2 Pipe Line Corrosion

W. H. Stewart, Chairman; Sun Pipe Line Co., P. O. Box 5292, Beaumont, Texas

Richard J. Emerson, Vice Chairman; El Paso Natural Gas Co., P. O. Box 1492, El Paso, Texas

T-2A Galvanic Anodes

M. A. Riordan, Chairman; Rio Engineering Co., Box 6035, Houston, Texas

R. L. Horst, Jr., Vice Chairman; Aluminum Co. of America, Box 1012, New Kensington, Pa.

T-2A-2 Development of Standard Accelerated Galvanic Anode Test Procedures

T-2B Anodes for Impressed Currents

Richard J. Emerson, Chairman; El Paso Natural Gas Co., P. O. Box 1492, El Paso, Texas

J. S. Dorsey, Vice Chairman; Southern California Gas Co., Box 3249, Terminal Annex, Los Angeles 54, Cal.

L. A. Hugo, Secretary; Engineering Department, Phillips Petroleum Co., Bartlesville, Okla.

T-2B-1 Sources of Impressed Current for Anodes

H. E. James, Chairman; Mississippi Valley Gas Co., Box 2447, W. Jackson Sta., Jackson 7, Miss.

T-2B-2 Ground Bed Design Data

F. I. Dorr, Chairman; 11838 Longleaf Lane, Houston 24, Texas

T-2B-4 Use of High Silicon Cast Iron for Anodes

W. A. Luce, Secretary; Duriron Co., Inc., Box 1019, Dayton 1, Ohio

T-2B-6 Deep Anodes

A. W. Peabody, Chairman: Ebasco Services, Inc., 2 Rector St., New York, N. Y.

T-2B-7 Use of Lead and Lead Alloys as Anodes

E. J. Mullarkey, Chairman; Lead Industries Ass'n, 292 Madison Ave., New York 17, N. Y.

T-2B-8 Anode Lead Wires

T. J. Maitland. Chairman; American Tel. & Tel. Co., 32 Avenue of the Americas, New York 13, N. Y.

T-2C Criteria for Cathodic Protection

L. C. Wasson, Chairman; A. O. Smith Corp., 3533 N. 27th St., Milwaukee, Wis.

A. W. Peabody, Vice Chairman; Ebasco Services, Inc., 2 Rector St., New York, N. Y.

T-2C-1 Basic Criteria

K. G. Compton, Chairman; Bell Telephone Labs., Murray Hill, N. J.

T-2C-2 Coupons, As A Criteria for Cathodic Protection

H. J. Keeling, Chairman; Consulting Engineer, 1780 E. Robertson Blvd., Los Angeles 35, Cal.

T-2C-3 History

T-2D Standardization of Procedures for Measuring Pipe Coating Leakage Conductance

L. F. Heverly, Chairman; Trans-Canada Pipe Lines Ltd., 150 Eglinton Ave. E, Toronto 12, Ontario, Canada

E. R. Allen, Jr., Vice Chairman; Humble Pipe Line Co., Engineering Lab, Rt. 7, Box 1400, Houston, Texas

T-2D-1 Short Insulated Sections of Low Conductance

Marshall E. Parker, Jr., Chairman; Consulting Engineer, 2023 Jean, Houston 23, Texas

T-2D-2 Inaccessible Locations, Such as Water Crossings

H. V. Beezley, Chairman; United Gas Pipe Line Co., Box 1407, Shreveport, La.

T-2D-3 Parallel Lines

L. A. Hugo, Chairman; Phillips Petroleum Co., Bartlesville, Okla.

T-2D-5 Pipe Observed to Be in a Stray Current Field

T-2E Internal Corrosion of Product Pipe Lines and Tanks

Ivy M. Parker, Chairman; Plantation Pipe Line Co., Box 1743, Atlanta, Ga.

A. W. Jasek, Vice Chairman; Humble Pipe Line Co., Drawer 2220, Houston 1, Texas

T-2F Internal Corrosion of Crude Oil Pipe Lines and Tanks

E. R. Allen, Temporary Chairman; Humble Pipe Line Co., Eng. Lab., Rt. 7, Box 1400, Houston, Texas

T-2G Coal Tar Coatings for Underground Use

T. F. P. Kelly, Chairman; Mavor-Kelly Co., 660 M & M Building, Houston 2, Texas

W. F. Fair, Jr., Vice Chairman; Koppers Co., Inc., Tar Products Div., Tech. Sec., 15 Plum St., Verona, Pa.

T-2H Asphalt Type Pipe Coatings

Frank B. Burns, Chairman; General Asphalts, Inc., Sub. of Kerr-McGee Oil Industries, Inc., P. O. Box 305, Wynnewood, Okla.

Wayne E. Broyles, Vice Chairman; Brance-Krachy Co., Inc., P. O. Box 1724, Houston 1, Texas

T-2H-2 Criteria to Be Used in Reporting on and Evaluating the Performance of Asphalt-Type Pipe Coatings

C. E. Lee, Chairman; Southern California Gas Co., Box 3249, Terminal Annex, Los Angeles 54, Cal.

T-2H-3 To Assemble and Present Service Histories of Asphalt-Type Pipe Coatings

John L. Rohwedder, Chairman; U. S. Corps of Engineers, Clock Tower Bldg., Rock Island, Ill.

T-2H-4 Asphalt-Type Internal Coating for Pipe Lines

F. B. Burns, Chairman; General Asphalts, Inc., Kerr-McGee Oil Industries, Inc., Box 305, Wynnewood, Okla.

T-2H-5 To Review and Encourage Publication of Technical Articles on Asphalt-Type Protective Coatings

L. S. Parker, Chairman; Fibreboard Paper Products Corp., 475 Brannan St., San Francisco 19, Cal.

T-2H-6 Asphalt Testing Technics on a Non-Technical Level

Lloyd F. Bramble, Chairman; Gulf States Asphalt Co., Inc., 1522 Melrose Bldg., Houston 2, Texas

T-2H-7 Asphalt Mastic Coating Specification

Robert L. Hansen, Chairman; Pipe Linings, Inc., Box 457, Wilmington, Cal.

T-2J Wrappers for Underground Pipe Line Coating

R. A. Brannon, Chairman: Humble Pipe Line Co., P. O. Box 2220, Houston 1, Texas

L. B. Nelson, Vice Chairman; Shell Pipe Line Corp., Box 2648, Houston, Texas

T-2J-1 Asbestos Felt

T-2J-2 Glass Wrap

T-2J-3 Glass Base Outer Wrap

F. B. Burns, Chairman; General Asphalts, Inc., Kerr-McGee Oil Industries, Inc., Box 305, Wynnewood, Okla.

T-2J-4 Rag Felt

L. S. Parker, Chairman; Fibreboard Paper Products Corp., 475 Brannan St., San Francisco 19, Cal.

T-2J-5 Rock Shield

Henry B. Hutten, Chairman; The Ruberoid Co., 500 5th Avenue, New York 36, New York

T-2K Prefabricated Plastic Film for Pipe Line Coating

J. J. Wise, Chairman; Arkansas-Louisiana Gas Co., Box 1734, Shreveport, La.

H. D. Segool, Vice Chairman; The Kendall Co., Polyken Sales Division, 309 West Jackson Blvd., Chicago 6, Ill.

T-2K-1 Standards

H. D. Segool, Chairman; Kendall Co., Polyken Sales Div., 309 W. Jackson Blvd., Chicago 6, Ill.

T-2K-2 Research and Development

Mel A. Henrickson, Chairman; Minnesota Mining & Mfg. Co., 900 Bush Ave., St. Paul, Minn.

T-2K-3 History and Results

F. E. Costanzo, Chairman; Manufacturers Light & Heat Co., 253 Ryan Drive, Pittsburgh 19, Pa.

T-2L Wax-Type Pipe Coatings and Component Wrappers

J. O. Mandley, Chairman; Michigan Consolidated Gas Co., 415 Clifford, Detroit 26, Mich.

I. E. Davis, Vice Chairman; 4405 Marland Dr., Columbus 24, Ohio

T-2M Aluminum Pipeline Corrosion

H. P. Godard, Chairman; Aluminium Lab. Ltd., P. O. Box 8400, Kingston, Ontario, Canada

R. S. Dalrymple, Vice Chairman; Reynolds Metals Co., Box 2346, Richmond 18, Va.

Charles F. Warnock, Secretary; Apartado 234, Maracaibo, Venezuela, S. A.

T-2M-1 Corrosion Behavior of Aluminum in Soil

H. L. Craig, Jr., Chairman; Reynolds Metals Co., Metallurgical Res. Labs., 4th & Canal Streets, Richmond 19, Va.

T-2M-2 Cathodic Protection of Aluminum

F. W. Hewes, Chairman; Canadian Protective Coating Ltd., 9420 91st St., Edmonton, Alberta, Canada

T-2M-3 Coating and Wrapping Aluminum

M. A. Riordan, Chairman; Rio Engineering Co., Box 6035, Houston, Texas

T-2M-4 Corrosion of Submarine Aluminum Pipe Lines in Lake Maracaibo, Venezuela

Charles F. Warnock, Chairman; Apartado 234, Maracaibo, Venezuela, S. A.

T-2M-5 Corrosion of Submarine Aluminum Pipelines in Sea Water

E. T. Wanderer, Chairman; Aluminum Co. of America, P. O. Box 1012, New Kensington, Pa.

T-2M-6 Corrosion of Submarine Aluminum Pipelines in Fresh Water

H. D. Walford, Chairman, Aluminum Co. of Canada, Ltd., Box 6090, Montreal 3, Quebec, Canada

T-2M-7 Internal Corrosion Problems for Handling Oilfield Brines, Crude Oil, and Natural Gases

Joseph U. Messenger, Chairman; Mobil Oil of Canada, Ltd., Mobil Oil Bldg., Calgary, Alberta, Canada

TECHNICAL PRACTICES COMMITTEE

T. J. Maitland, Chairman; American Tel. & Tel. Co., 32 Avenue of the Americas, New York 13, New York

Jack L. Battle, Vice Chairman; Humble Oil & Refining Co., P. O. Box 2180, Houston, Texas

Chairmen of T-1 through T-9 are members of this committee. The President, Vice-President and Executive Secretary of NACE are Ex-Officio members of this committee.

T 3 General

D. A. Vaughan, Chairman; Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio

L. C. Rowe, Vice Chairman; Research Labs., General Motors Corp., 12 Mile & Mound Roads, Warren, Mich.

Directory of NACE Technical Committee Officers

T-3A Corrosion Inhibitors

L. C. Rowe, Chairman; Research Labs., General Motors Corp., 12 Mile & Mound Roads, Warren, Mich.

A. J. Freedman, Vice Chairman; Nalco Chemical Co., 6216 West 66th Place, Chicago 38, Ill.

T-3A-2 Methods of Testing & Screening Corrosion Inhibitors

(Chairman to be Selected)

T-3A-3 Materials Available for and Application of Corrosion Inhibitors

L. A. Timm, Chairman; Saran Lined Pipe Co., 6 W. Broad St., Room 410, Bethlehem, Pa.

T-3B Corrosion Products

A. H. Roebuck, Chairman; Western Company, Fort Worth Club Bldg., P. O. Box 186, Fort Worth 1, Texas

D. A. Vaughan, Vice Chairman; Battelle Memorial Institute, 505 King Avenue, Columbus Ohio

T-3B-1 Corrosion Products Bibliography

R. T. Foley, Co-Chairman; General Electric Co., General Eng. Lab., Rm. 2004, Bldg. 37, Schenectady, N. Y.

E. L. Simons, Co-Chairman; General Electric Co., Res. Lab., Box 1088, Schenectady, N. Y.

T-3B-2 ASTM Liaison

D. A. Vaughan, Chairman; Battelle Memorial Institute, 505 King Ave., Columbus, Ohio

T-3B-3 Corrosion Products Analytical Techniques

H. P. Godard, Chairman; Aluminium Lab. Ltd., Box 8400, Kingston, Ontario, Canada

T-3C Annual Losses Due to Corrosion

S. K. Coburn, Chairman; Applied Research Lab., United States Steel Corp., Monroeville, Pa.

T-3D Instruments for Measuring Corrosion

E. H. Thalmann, Chairman; Ebasco Services, Inc., 2 Rector St., New York, N. Y.

F. W. Ringer, Vice Chairman; 7 Hampden Ave., Narberth, Pa.

T-3D-1 Electrical Holiday Inspection of Coatings

W. A. Broome, Chairman; Arkansas-Louisiana Gas Co., Box 1734, Shreveport 4, La.

T-3E Railroads

L. J. Nicholas, Chairman; Pullman Co., 165 N. Canal St., Chicago 6, Ill.

G. M. Magee, Vice Chairman; Assoc. American Railroads, 3140 South Federal Street, Chicago, Ill.

T-3E-1 Corrosion of Railroad Tank Cars

C. M. Jekot, Vice Chairman; DeSoto Paint & Varnish Co., P. O. Box 186, Garland, Texas

T-3E-2 Corrosion in Railroad Hopper Cars

C. L. Crockett, Chairman; Norfolk and Western Railway, Motive Power Dept., Roanoke, Va.

T-3F Corrosion by High Purity Water

R. U. Blaser, Chairman; Research Center, Babcock & Wilcox Co., Box 835, Alliance, Ohio

M. C. Bloom, Vice Chairman; Metallurgy Div., Naval Research Lab., Washington 20, D. C.

T-3F-2 Inhibitors

R. C. Ulmer, Chairman; Manager Research, Combustion Engineering Co., Windsor, Conn.

T-3F-3 Corrosion Products

W. L. Pearl, Chairman; General Electric Company, Atomic Power Equipment Dept., Box 254, San Jose, Cal.

T-3F-6 Intercommittee Activities

E. P. Partridge, Chairman; Hall Labs., Inc., Box 1346, Pittsburgh, Pa.

T-3F-7 Bibliography

W. K. Boyd, Chairman; Battelle Memorial Institute, 505 King Ave., Columbus, Ohio

T-3G Cathodic Protection

T. P. May, Chairman; International Nickel Co., Inc., Box 262, Wrightsville Beach, N. C.

J. L. Miller, Secretary; National Carbon Co., Div. of Union Carbide Co., Box 6087, Cleveland 1, Ohio

T-3G-1 Cathodic Protection of Hull Bottoms of Ships

L. P. Sudrabin, Chairman; Electro Rust-proofing Corp., Box 178, Newark, New Jersey

H. S. Preiser, Vice Chairman; 6904 Leesville Blvd., North Springfield, Va.

T-3G-2 Cathodic Protection of Heat Exchangers

R. B. Teel, Chairman; International Nickel Co., Inc., 333 N. Michigan Ave., Chicago 1, Ill.

T-3G-3 Cathodic Protection of Process Equipment

A. A. Brouwer, Chairman; The Dow Chemical Co., 52 Bldg., Midland, Michigan

T-3H Tanker Corrosion

W. S. Quimby, Chairman; Res. & Tech. Dept., Texaco, Inc., Box 509, Beacon, New York

T4 Utilities

J. B. Prime, Jr., Chairman; Florida Power & Light Co., Box 3100, Miami 30, Fla.

A. L. Ayres, Vice Chairman; New Jersey Bell Tel. Co., 540 Broad St., Rm. 1600, Newark 2, N. J.

T-4A Effects of Electrical Grounding on Corrosion

O. W. Zastrow, Chairman; Electric Engineering Div., Rural Electrification Adm., USDA, Washington 25, D. C.

C. L. Mercer, Vice Chairman; Southwestern Bell Tel. Co., Box 58, Westfield, Texas

T-4A-3 Methods and Materials for Grounding

I. C. Dietze, Chairman; L. A. Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles 54, Cal.

T-4A-4 Coordination of Utility Grounding Practices

A. F. Minor, Chairman; American Tel. & Tel. Co., 195 Broadway, New York 7, N. Y.

T-4B Corrosion of Lead and Other Metallic Cable Sheaths

H. M. Clayton, Vice Chairman; Memphis Gas, Light and Water Div., Box 388, Memphis, Tenn.

T-4C Non-Metallic Sheaths and Coatings

A. W. MacKay, Chairman; Detroit Edison Co. 2000 Second Ave., Detroit 26, Mich.

H. E. Kroon, Vice Chairman; 4956 Dobson St., Skokie, Ill.

T-4C-1 Practices and Experience with Protective Jackets for Outside Plant Lead and Aluminum Sheathed Power Cables

L. O. McCormick, Chairman; Baltimore Gas & Electric Co., Madison Street Building, Baltimore 3, Md.

T-4C-2 Communication Cables with Corrosion Resistant Covering or Coating

A. F. Minor, Chairman; American Tel. & Tel. Co., 195 Broadway, New York 7, N. Y.

T-4D Corrosion by Deicing Salts

K. G. Compton, Chairman; Bell Telephone Laboratories, Murray Hill, New Jersey

L. C. Rowe, Vice Chairman; Research Labs., General Motors Corp., 12 Mile & Mound Roads, Warren, Mich.

T-4D-1 Procedures for Conducting Field Tests Below Ground

F. E. Kulman, Chairman, Consolidated Edison Co. of New York, Inc., 4 Irving Place, New York, N. Y.

T-4D-2 Coordination of Field Programs Between Cities and Transportation Companies

George Illig, Chairman; Calgon, Inc., 323 Fourth Ave., Pittsburgh, Penn.

T-4E Corrosion by Domestic Waters

J. F. J. Thomas, Chairman; Industrial Waters Section, Dept. of Mines & Technical Surveys, 40 Lydia Street, Ottawa, Ontario, Canada

R. W. Lane, Vice Chairman; Illinois State Water Survey, Water Resources Bldg., 605 E. Springfield, Champaign, Ill.

T-4E-1 Hot Water Tank Corrosion

H. C. Fischer, Chairman; Thermo Craft Corp., Montville, N. J.

T-4F Materials Selection for Corrosion Mitigation in the Utility Industry

W. T. Burgess, Chairman; Metropolitan Utilities District, 18th & Harney Street, Omaha 2, Nebraska

I. C. Dietze, Vice Chairman; L. A. Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles 54, Cal.

T-4F-1 Materials Selection in the Water Industry

Daniel Cushing, Chairman; 148 State St., Boston, Massachusetts

Chester Anderson, Vice Chairman; The Crane Co., 836 South Michigan Avenue, Chicago 5, Ill.

Peter Kahn, Secretary; Metcalf & Eddy, 1300 Statler Bldg., Boston, Mass.

T-4F-2 Materials Selection in the Electric Industry

F. E. Kulman, Chairman; Consolidated Edison Co. of New York, Inc., 4 Irving Place, New York 3, N. Y.

T-4G Protection of Pipe Type Cables

F. E. Kulman, Chairman; Consolidated Edison Co. of N. Y., Inc., 4 Irving Place, New York 3, N. Y.

T-4H Tests and Surveys of Cable Sheaths

H. W. Dieck, Chairman; Long Island Lighting Co., 175 Old Country Road, Hicksville, N. Y.

R. W. Ackermann, Vice Chairman; American Tel. & Tel. Co., 1014 Vine Street, Cincinnati 2, Ohio

T-4J Cathodic Protection of Cable Sheaths

Harry E. Kroon, Chairman; 4956 Dobson St., Skokie, Ill.

Roy O. Dean, Vice Chairman; Pacific Gas and Electric Co., 4245 Hollis St., Emeryville 8, Cal.

T-4J-1 Interference from Cathodic Protection Rectifiers

C. L. Mercer, Chairman; Southwestern Bell Tel. Co., P. O. Box 58, Westfield, Texas

T5 Corrosion Problems in the Process Industries

C. P. Dillon, Chairman; Union Carbide Chemicals Co., Div. of Union Carbide Corp., P. O. Box 2831, Charleston, W. Virginia

W. H. Burton, Vice Chairman; General Chemical Div., Allied Chemical Corp., 1100 Line St., Camden 3, N. J.

T-5A Corrosion in Chemical Processes

W. H. Burton, Chairman; General Chemical Div., Allied Chemical Corp., 1100 Line St., Camden 3, N. J.

L. W. Gleekman, Vice Chairman; Wyandotte Chemicals Corp., 1609 Biddle Ave., Wyandotte, Mich.

T-5A-1 Inorganic Acids and Derivatives

N. D. Groves, Chairman; Carpenter Steel Co., 101 West Bern St., Reading, Pa.

T. F. Degnan, Vice Chairman; 701 W. 22 St., Wilmington 2, Del.

T-5A-2 Organic Acids and Derivatives

R. H. Scott, Chairman; Route 2, Box 2, Bishop, Texas

T-5A-3 Alkali Environment

George P. Gladis, Chairman; International Nickel Co., Inc., 67 Wall Street, New York 5, N. Y.

T-5B High Temperature Corrosion

David Roller, Chairman; Magna Products, Inc., 11808 South Bloomfield Ave., Santa Fe Springs, Cal.

D. W. McDowell, Jr., Vice Chairman; International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

T-5C Corrosion by Cooling Waters

T-5C-1 Corrosion by Cooling Waters (South Central Region)

J. M. Brooke, Chairman; Phillips Petroleum Co., Sweeny Refinery, Sweeny, Texas

A. S. Krisher, Vice Chairman; Monsanto Chemical Co., Plastics Div., Texas City, Texas

L. Miller Rogers, Secretary; Union Carbide Chemicals Co., P. O. Box 471, Texas City, Texas

T-5C-2 Corrosion by Cooling Waters (North Central Region)

William A. Hess, Chairman; Standard Oil Co. (Ohio), Midland Bldg., Cleveland 15, Ohio

D. B. Jones, Vice Chairman; Goodyear Atomic Corp., P. O. Box 628, Portsmouth, Ohio

Francis E. Novitskie, Secretary; Shell Oil Co., Wood River Refinery, Box 262, Wood River, Ill.

T-5C-3 Corrosion by Cooling Waters (Northeast Region)

Sidney Sussman, Temporary Chairman; Water Service Lab., Inc., 615 West 131 St., New York 27, N. Y.

T-5D Plastic Materials of Construction

R. E. Gackenbach, Chairman; American Cyanamid Co., 30 Rockefeller Plaza, New York 20, N. Y.

Otto H. Fenner, Vice Chairman; Monsanto Chemical Co., 1700 South Second St., St. Louis 77, Mo.

T-5E Stress Corrosion Cracking of Austenitic Stainless Steel

E. V. Kunkel, Chairman; Celanese Corp. of America, P. O. Box 428, Bishop, Texas

H. R. Copson, Vice Chairman; 18 Hampton St., Cranford, N. J.

T6 Protective Coatings

O. H. Fenner, Chairman; Monsanto Chemical Co., 1700 South Second St., St. Louis 77, Mo.

R. H. Bacon, Vice Chairman; Dow Chemical Co., Maintenance Staff, Freeport, Texas

T-6A Organic Coatings and Linings for Resistance to Chemical Corrosion

L. S. Van Delinder, Chairman; Union Carbide Chemicals Co., Dev. Dept., South Charleston, W. Va.

V. B. Volkening, Vice Chairman; Dow Chemical Co., Route 1, Freeport, Texas

T-6A-1 Rubber Linings

R. McFarland, Jr., Chairman; Hills-McCanna Co., 400 Maple Street, Carpentersville, Illinois

T-6A-2 Vinyl Coatings

C. G. Munger, Chairman; Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal.

T-6A-3 Vinylidene Chloride Polymers

T-6A-4 Phenolics

Forest Baskett, Chairman; Sheet Metal Engineers, Inc., Box 9384, Houston, 11, Texas

T-6A-5 Polyethylene

L. S. Van Delinder, Chairman; Carbide & Carbon Chemicals Co., South Charleston, W. Va.

T-6A-6 Neoprene

D. J. Kelly, Chairman; E. I. du Pont de Nemours & Co., Inc., Box 406, Wilmington, Del.

Directory of NACE Technical Committee Officers

T-6A-7 Thermosetting Coal Tar Coatings
Woodrow E. Kemp, Chairman; Koppers Co., Inc., 15 Plum St., Verona, Pa.

T-6A-9 Furanes
C. G. Munger, Chairman; Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal.

T-6A-10 Polyesters
D. D. Cone, Chairman; 1806 Florida, Baytown, Texas

T-6A-11 Epoxies
C. G. Munger, Chairman; Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal.

T-6A-12 Fluorocarbons
Sylvan B. Falck, Chairman; Inner-Tank Lining Corp., 4777 Eastern Ave., Cincinnati 26, Ohio

T-6A-13 Chlorinated Rubbers
R. McFarland, Chairman; Hills-McCanna Co., 400 Maple St., Carpentersville, Ill.

T-6A-14 Organic-Brick Covered
T-6A-15 Rigid Vinyls
C. G. Munger, Chairman; Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal.

T-6A-16 Coal Tar Coatings
T-6A-17 Polyurethanes
E. R. Wells, Chairman; Mobay Chemical Co., Research Laboratories, New Martinsville, W. Va.

T-6A-18 Hypalon
D. J. Kelly, Chairman; E. I. du Pont de Nemours & Co., Inc., Box 406, Wilmington, Del.

T-6A-19 Asphalts
T-6A-20 Plastisols
Otto H. Fenner, Chairman; Monsanto Chemical Co., 1700 South Second St., St. Louis 77, Mo.

T-6A-21 Compile Reports for Binding Into One Volume

T-6B Protective Coatings for Resistance to Atmospheric Corrosion

Robert P. Suman, Chairman; Pittsburgh Plate Glass Co., P. O. Box 21114, Houston 26, Texas

M. W. Belue, Jr., Vice Chairman; General Plant Engineering Dept., Champion Paper & Fibre Co., Hamilton, Ohio

T-6B-1 Linseed and Other Drying Oils
John D. Keane, Chairman; Steel Structures Painting Council, 4400 5th Ave., Pittsburgh 13, Pa.

T-6B-3 Straight Phenolic Oil Varnish
John W. Nee, Chairman; Briner Paint Mfg. Co., 3713 Agnes St., Corpus Christi, Texas

T-6B-4 Modified Phenolic Oil Varnish
T-6B-5 Straight Alkyd Varnish
William F. Conners, Chairman; Humble Oil & Refining Co., Box 2180, Houston, Texas

Robert M. Ives, Jr., Vice Chairman; Sales Tech. Service Div., Humble Oil & Refining Co., P. O. Box 2180, Houston, Texas

T-6B-6 Modified Alkyd Varnish
Robert M. Ives, Jr., Chairman; Sales Tech. Service Div., Humble Oil & Refining Co., P. O. Box 2180, Houston, Texas

William F. Conners, Vice Chairman; Humble Oil & Refining Co., Box 2180, Houston, Texas

T-6B-7 Epoxy Esters
Howell C. Owens, Chairman; Coast Paint & Lacquer Co., Inc., Box 1113, Houston 1, Texas

John G. Raudsep, Vice Chairman; Shell Chemical Co., P. O. Box 2099, Houston 1, Texas

T-6B-8 Epoxy (Amine Cured)
John G. Raudsep, Chairman; Shell Chemical Co., P. O. Box 2099, Houston 1, Texas

Howell C. Owens, Vice Chairman; Coast Paint & Lacquer Co., Inc., Box 1113, Houston 1, Texas

T-6B-9 Chlorinated Rubber
G. E. Ashburn, Chairman; Napko Corp., Box 14126, Houston 21, Texas

T-6B-10 Vinyls
John I. Richardson, Chairman; Amercoat Corporation, 4809 Firestone Blvd., South Gate, Cal.

T-6B-11 Zinc Filled Inorganic Coatings
F. Parker Helms, Chairman; Union Carbide Chemicals Co., P. O. Box 471, Texas City, Texas

T-6B-13 Asphalt
C. C. Allen, Chairman; Anderson-Prichard Oil Corp., 1000 Liberty Bank Bldg., Oklahoma City 2, Okla.

T-6B-14 New Developments
Joseph E. Rench, Chairman; Napko Corp., P. O. Box 14126 Houston 21, Texas

T-6B-15 Heat Resistant Silicones
T-6B-16 Polyurethanes
E. R. Wells, Chairman; Mobay Chemical Co., Coatings Res., Research Lab., New Martinsville, W. Va.

T-6B-17 Chemical Cured Coal Tar Coatings
R. H. Goodnight, Chairman; Cook Paint & Varnish Co., Box 389, North Kansas City, Mo.

T-6B-18 Zinc Coatings
J. W. Cushing Jr., Chairman; Carboline Co., #32 Hanley Industrial Court, St. Louis 17, Mo.

T-6B-19 Galvanizing
Ray Vickers, Chairman; Nowery J. Smith Co., Box 7398, Houston 8, Texas

J. A. Heath, Jr., Vice Chairman; Dow Chemical Co., Freeport, Texas

T-6B-20 Metallizing
R. J. McWaters, Chairman; Metco, Inc., 1101 Prospect Ave., Westbury, L. I., N. Y.

F. W. Gartner, Jr., Vice Chairman, F. W. Gartner Co., Box 1303, Houston 1, Texas

T-6C Protective Coatings for Resistance to Marine Corrosion

L. S. Van Delinder, Temporary Chairman, Union Carbide Chemicals Co., Development Dept., South Charleston, W. Va.

T-6D Industrial Maintenance Painting
F. Parker Helms, Chairman; Union Carbide Chemicals Co., P. O. Box 471, Texas City, Texas

D. D. Cone, Vice Chairman; 1806 Florida, Baytown, Texas

T-6D-1 Economics of Maintenance Painting
Stanley L. Lopata, Chairman; Carboline Company, #32 Hanley Industrial Center, St. Louis 17, Mo.

T-6D-2 Standardization of Scope of Painting Specifications
L. L. Sline, Chairman; Sline Industrial Painters, 2162 Gulf Terminal Dr., Houston 23, Texas

T-6D-4 Specifications for Shop Cleaning & Priming
L. L. Sline, Chairman; Sline Industrial Painters, 2162 Gulf Terminal Drive, Houston 23, Texas

T-6D-5 Painter Safety
Lowell S. Hartman, Chairman; Hartman-Walsh Painting Co., 5078 Easton St., St. Louis 13, Mo.

T-6D-6 Painter Education
C. W. Sisler, Chairman; John F. Queeny Plant, Monsanto Chemical Co., 1700 South Second St., St. Louis, Mo.

T-6D-7 Industrial Maintenance Painting Problems
C. R. Martinson, Chairman; Monsanto Chemical Co., 800 N. Lindberg Blvd., St. Louis 66, Mo.

T-6D-8 Contract vs Plant Maintenance Painting
Charles E. Fox, Chairman; Sline Industrial Painters, 2162 Gulf Terminal Dr., Houston, Texas

T-6D-9 Engineering Design For Corrosion
J. L. Weis, Chairman; Maintenance Engineer, International Minerals & Chemical Corp., Box 71, Carlsbad, N. M.

T-6D-10 Training Films
E. W. Oakes, Chairman; E. W. Oakes Co., 6443 Jefferson Dr., Houston 23, Texas

T-6E Protective Coatings in Petroleum Production
C. J. Fritts, Chairman; Socony Paint Products Co., Box 1740, Houston, Texas

F. E. Blount, Vice Chairman; Socony Mobil Labs., Box 900, Dallas 1, Texas

T-6F Protective Interior Linings, Application and Methods
W. P. Cathcart, Chairman; Tank Lining Corp., Oakdale, Pa.

Bernard Saffian, Vice Chairman; Chamberlain Lab., U. S. Stoneware Co., Fishcreek Road, Box 624, Stow, Ohio

James Cogshall, Secretary; Pennsalt Chemical Corp., Corrosion Engr. Products Dept., Natrona, Pa.

T-6F-1 Curing
K. G. Lefevre, Chairman; Metalweld, Inc., 2617 Hunting Park Ave., Philadelphia 29, Pa.

T-6F-2 Surface Preparation
H. T. Rudolf, Chairman; Atlantic Coatings Co., Inc., Box 2976, Jacksonville, Fla.

John I. Richardson, Vice Chairman; Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal.

T-6F-3 Inspection
J. L. Barker, Jr., Chairman; Works Engineering Dept., Union Carbide Chemicals Co., Box 8004, Bldg. 82-821, S. Charleston 3, W. Va.

T-6F-4 Safety
Jens Nielsen, Chairman; Shipper's Car Line, Div. of ACF Industries Inc., 750 Third Ave., New York 17, N. Y.

T-6F-5 Application
Robert E. Robinson, Chairman; Hooker Chemical Corp., Box 344, Niagara Falls, N. Y.

T-6F-6 Ethics
W. P. Cathcart, Chairman; Tank Lining Corp., Oakdale, Pa.

T-6G Surface Preparation for Organic Coatings
Joseph Bigos, Chairman; U. S. Steel Corp., Applied Res. Lab., Monroeville, Pa.

John D. Keane, Vice Chairman; Steel Structures Painting Council, 4400 5th Ave., Pittsburgh 13, Pa.

T-6H Glass Linings and Vitreous Enamels
R. McFarland, Jr., Chairman; Hills-McCanna Co., 400 Maple St., Carpentersville, Ill.

D. K. Priest, Vice Chairman; Pfaudler Div., Pfaudler Permutit, Inc., 1000 West Avenue, Rochester 11, N. Y.

D. B. Johnson, Secretary; Glascote Products, Inc., 20900 St. Clair Ave., Cleveland 17, Ohio

T-6H-1 Glass Coatings
T-6H-2 Porcelain Enamel Coatings
A. R. Leyerle, Chairman; Vitreous Steel Products Co., P. O. Box 3991, Cleveland 20, Ohio

T-6J Protective Coating Application Problems

T-6J Los Angeles Area, Protective Coating Application Problems
Flora L. Davis, Chairman; 6173 North Ibbetson, Lakewood, Cal.

R. E. Hall, Vice Chairman; Union Oil Co. of Cal., Res. Center, Brea, Cal.

Newell W. Tune, Secretary; L. A. Water & Power, 510 East 2nd St., Los Angeles, Cal.

T-6J-1 Specification Writing
Newell Tune, Chairman; L. A. Water & Power, 510 East Second St., Los Angeles, Cal.

T-6J-2 Application Procedure
David Jaffee, Chairman; Williams Waterproofing Co., 3107 Fletcher Dr., Los Angeles, Cal.

T-6J-3 Inspection Techniques
Newell W. Tune, Chairman; Los Water & Power, 510 E. 2nd St., Los Angeles 54, Cal.

T-6J-4 Cost Evaluation
W. J. Frith, Chairman; Service Coating Corp., P. O. Box 524, Wilmington, Cal.

T-6R Protective Coatings Research
J. H. Cogshall, Chairman; Pennsalt Chemicals Corp., Corrosion Engineering Products Dept., Natrona, Pa.

T7 Corrosion Coordinating Committee

C. L. Mercer, Chairman; Southwestern Bell Tel. Co., P. O. Box 58, Westfield, Texas

Paul C. Hoy, Vice Chairman; Dayton Power & Light Co., 25 North Main St., Dayton, Ohio

T-7A Northeast Region Corrosion Coordinating Committee

C. A. Erickson, Chairman; Peoples Natural Gas Co., Two Gateway Center, Pittsburgh 22, Pa.

New Jersey Committee on Corrosion
R. J. Bishop, Chairman, Public Service Electric & Gas Co. of N. J., 80 Park Place, Newark, N. J.

C. W. Beggs, Vice Chairman; Public Service Electric & Gas Co., 80 Park Place, Newark, N. J.

E. T. Pearson, Secretary; Public Service Electric & Gas Co., 200 Boyden Ave., Maplewood, N. J.

Greater New York Committee on Corrosion
W. E. Ripley, Chairman; New York Central Railroad, 466 Lexington Ave., New York, N. Y.

F. E. Kulman, Vice Chairman; Consolidated Edison Co. of N. Y., Inc., 4 Irving Place, New York 3, N. Y.

J. Richard Recame, Secretary; New York Telephone Co., 199-06 93rd Ave., 3rd Floor, Hollis 23, N. Y.

Western New York State Corrosion Committee
A. Fini, Chairman; Niagara Mohawk Power Corp., 93 Dewey Ave., Buffalo 14, N. Y.

R. M. Keller, Vice Chairman; Atlantic Pipeline Co., 5368 Magnolia, Philadelphia, Pa.

J. V. Adkin, Secretary; Rochester Gas & Electric Corp., 89 East Ave., Rochester 4, N. Y.

Southern W. Virginia Corrosion Coordinating Committee
K. R. Gosnell, Chairman; Development Dept., Union Carbide Chemicals Co., South Charleston, W. Va.

P. F. Sweeney, Vice Chairman; Chesapeake & Potomac Tel. Co. of W. Va., 816 Lee St., Charleston 5, W. Va.

James A. Parker, Secretary; United Fuel Gas Co., P. O. Box 1273, Charleston 25, W. Va.

Greater Boston Electrolysis Committee
J. J. Molloy, Chairman; Cambridge Electric Light Co., 46 Blackstone St., Cambridge 39, Mass.

H. L. Pratt, Vice Chairman; New England Electric System, Gas Div., 157 Pleasant St., Malden, Mass.

Louis R. Delaplace, Secretary; Boston Edison Co., 1165 Massachusetts Ave., Dorchester 25, Mass.

Western Pennsylvania Corrosion Committee
John B. Vrable, Chairman; New York State Natural Gas Corp., Two Gateway Center, Pittsburgh 22, Pa.

G. C. Picht, Jr., Vice Chairman; American Tel. & Tel. Co., 429 Fourth Ave., Pittsburgh 19, Pa.

Directory of NACE Technical Committee Officers

F. E. Costanzo, Secretary; Manufacturers Light & Heat Co., 253 Ryan Drive, Pittsburgh 19, Pa.

Pittsburgh Corrosion Committee

C. M. Rutter, Jr., Chairman; Equitable Gas Co., 420 Blvd. of Allies, Pittsburgh 19, Pa.

D. W. Kissinger, Vice Chairman; Duquesne Light Co., 1241 Reedsdale Street, Pittsburgh 33, Pa.

E. W. Steel, Secretary; Bell Telephone Co., of Pa., 201 Stanwix St., 3rd Floor, Pittsburgh 22, Pa.

T-7B North Central Region Corrosion Coordinating Committee

Paul C. Hoy, Chairman; Dayton Power & Light Co., 25 N. Main St., Dayton, Ohio

J. O. Mandley, Vice Chairman; Michigan Consolidated Gas Co., 415 Clifford, Detroit 26, Mich.

Chicago Region Committee on Underground Corrosion

C. N. Crowe, Chairman; Standard Oil Co. (Ind.), Box 5910-A, Chicago 80, Ill.

H. E. Kroon, Vice Chairman; 4956 Dobson St., Skokie, Ill.

R. J. Havel, Secretary; 20 North Wacker Dr., Room 720, Chicago 6, Ill.

Columbus and Central Ohio Committee on Corrosion

H. E. Browne, Chairman; Ohio Bell Tel. Co., 215 W. Second St., Dayton, Ohio

K. A. Gelston, Vice Chairman; Pennsylvania R. R. Co., 230 E. 9th St., Cincinnati 2, Ohio

J. H. Fitzgerald, Secretary; Columbia Gas System Service Corp., Box 2318, Columbus 16, Ohio

Toledo and Northwestern Ohio Committee on Corrosion

O. V. Henrion, Chairman; Ohio Bell Telephone Co., 121 Huron St., Toledo 4, Ohio

J. D. Griffin, Vice Chairman; Ohio Fuel Gas Co., District Dept., 333 South Erie St., Toledo 4, Ohio.

F. A. Liedel, Secretary; Toledo Edison Co., 420 Madison Ave., Toledo 4, Ohio

Detroit Committee on Electrolysis

C. Chapin, Chairman; Dept. of Water Supply, 701 Water Board Bldg., Detroit 26, Mich.

P. Hough, Vice Chairman; Michigan Bell Telephone Co., 3800 Cadillac Tower, Detroit 26, Mich.

E. E. Westerhof, Secretary-Treasurer; Consumers Power Co., 212 W. Michigan Ave., Jackson, Mich.

Joint Electrolysis Committee of Various Utility Companies of Chicago

R. I. Perry, Chairman; Commonwealth Edison Co., 72 W. Adams St., Rm. 818, Chicago 90, Ill.

H. C. Boone, Secretary; Peoples Gas, Light & Coke Co., 122 S. Michigan Ave., Rm. 1732, Chicago 3, Ill.

T-7C Southeast Region Corrosion Coordinating Committee

E. W. Seay, Jr., Chairman; The Chesapeake & Potomac Tel. Co. of Va., 5550 Lynn Street, Norfolk 13, Va.

The Louisville (Ky.) Joint Electrolysis Committee

Stuart H. Gates, Chairman; Southern Bell Tel. & Tel. Co., 534 Armory Place, Rm. 505, Box 538, Louisville, Ky.

John L. Gray, Vice Chairman; Louisville Gas & Electric Co., Louisville, Ky.

Walter Zell, Secretary; Louisville Gas & Electric Co., Louisville, Ky.

South Florida Corrosion Control Committee

J. B. Prime, Jr., Chairman; Florida Power & Light Co., P. O. Box 3100, Miami 30, Fla.

J. S. Frink, Vice Chairman; 6220 Leonardo, Coral Gables, Fla.

C. H. A. Montague, Secretary; Peoples Gas System, 564 N. E. 125 St., North Miami 61, Fla.

Tidewater Corrosion Committee

E. W. Seay, Jr., Chairman; The Chesapeake & Potomac Tel. Co. of Va., 5550 Lynn Street, Norfolk 13, Va.

J. W. Berryman, Jr., Secretary; 3463 Fletcher Drive, Norfolk 13, Va.

T-7D South Central Region Corrosion Coordinating Committee

C. L. Mercer, Chairman; Southwestern Bell Tel. Co., Box 58, Westfield, Texas

C. L. Woody, Vice Chairman; United Gas Corporation, Box 2628, Houston, Texas

Houston Corrosion Coordinating Committee

C. L. Mercer, Chairman; Southwestern Bell Telephone Co., Box 58, Westfield, Texas

San Antonio Area Corrosion Committee

Carl M. Thorn, Vice Chairman; Southwestern Bell Tel. Co., P. O. Box 2540, San Antonio 6, Texas

Denver Metro Committee on Corrosion

H. L. Goodrich, Chairman; American Tel. & Tel. Co., 810 4th St., Denver 2, Colo.

F. F. Hassoldt, Vice Chairman; Denver Board of Water Commissioners, 144 West Colfax Ave., Denver, Colo.

H. A. Emery, Secretary; Public Service Co. of Colo., Gas Engineering Dept., Box 840, Denver 1, Colo.

T-7E Western Region Corrosion Coordinating Committee

I. C. Dietze, Chairman; L. A. Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles 54, Cal.

W. G. Collins, Vice Chairman; Pacific Tel. & Tel. Co., 760 Market St., Rm. 1138, San Francisco 2, Cal.

Central California Cathodic Protection Committee

J. A. Bessom, Chairman; Richfield Oil Corp., Box 147, Bakersfield, Cal.

C. E. Titus, Vice Chairman; Shell Oil Co., Box 329, Tracy, Cal.

T. J. Helms, Secretary; Superior Oil Co., Box 1031, Bakersfield, Cal.

San Diego County Underground Corrosion Committee

Ray Ditto, Chairman; California Water & Telephone Co., 386 Third Avenue, Chula Vista, Cal.

R. E. Hall, Vice Chairman; Union Oil Co., Research Center, Brea, Cal.

F. O. Waters, Secretary; 6326 Montezuma Road, San Diego 15, Cal.

Electrolysis Committee of Southern California

I. C. Dietze, Chairman; L. A. Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles 54, Cal.

F. F. Knapp, Secretary; Box 126, Vista, Cal.

The Joint Committee for the Protection of Underground Structures in the East Bay Cities

L. B. Hertzberg, Chairman; East Bay Municipal Utility District, 2127 Adeline St., Oakland, Cal.

W. G. Collins, Vice Chairman; Pacific Tel. & Tel. Co., 760 Market St., Rm. 1138, San Francisco 2, Cal.

C. K. Notley, Secretary-Treasurer; 1132 Walnut St., Berkeley 7, Cal.

The San Francisco Committee on Corrosion

A. J. Badura, Chairman; Western Union Tel. Co., 125 - 12th St., Oakland, Cal.

G. C. Hughes, Secretary; Pacific Tel. & Tel. Co., No. 1 McCoppin St., San Francisco, Cal.

T-7F Canadian Region Corrosion Coordinating Committee

C. L. Roach, Chairman; Bell Telephone of Canada, Room 1425, 1050 Beaver Hall Hill, Montreal, Quebec, Canada

Peter Dunkin, Vice Chairman; Union Gas Co. of Canada, Ltd., 48 Fifth St., Chatham. Ontario, Canada

Southern Ontario Committee on Electrolysis

L. F. Heverly, Chairman; Trans-Canada Pipe Lines Ltd., 150 Eglinton Ave. East, Toronto 12 Ontario, Canada

D. W. Lemon, Vice Chairman; Sarnia Products Pipe Line, Imperial Oil Ltd., Box 380, Waterdown, Ontario, Canada

R. C. Campbell, Secretary; United Gas Ltd., 360 Strathearne Ave. North, Hamilton, Ontario, Canada

T8 Refining Industry Corrosion

Cecil Phillips, Jr., Chairman; Humble Oil & Refining Co., Humble Division, 1506 East Texas Ave., Baytown, Texas

R. D. Merrick, Vice Chairman; Esso Research & Engineering Co., Box 209, Madison, N. J.

F. B. Hamel, Secretary; Standard Oil Co. of Ohio, Midland Bldg., Cleveland, Ohio

T-8A Chemical Cleaning

K. R. Walston, Chairman; Standard Oil Co. (Ind.), 2400 New York Ave., Whiting, Ind.

C. M. Loucks, Vice Chairman; Consulting Chemist, 23800 Center Ridge Rd., Westlake, Ohio

R. L. Hildebrand, Secretary; Sinclair Refining Co., 400 East Sibley Blvd., Harvey, Ill.

T-8B Refinery Industry Corrosion, Los Angeles Area

E. B. Marquand, Vice Chairman; Aluminum Co. of America, 1145 Wilshire Blvd., Los Angeles 17, Cal.

C. M. Cooper, Secretary; Standard Oil Co. of Cal., El Segundo Refinery, El Segundo, Cal.

T9 Marine Biological Deterioration

A. P. Richards, Chairman; Clapp Laboratories, Washington St., Duxbury, Massachusetts

T-9A Biological

Charles E. Lane, Chairman; Marine Laboratory, University of Miami, Coral Gables 34, Fla.

T-9B Preservatives and Their Appraisal

Harry Hochman, Chairman; 23652 Collins St., Woodland Hills, Cal.

V. B. Volkening, Vice Chairman; Route 1, Freeport, Texas

TECHNICAL ARTICLES SCHEDULED FOR PUBLICATION

February Issue

Symposium on Corrosion of Iron and Tin

1. Corrosion Resistance of Electrolytic Tin Plate—Part 1: Electrochemical Studies of Tin, Iron-Tin Alloy and Steel in Air-Free Citric Acid Media, by G. G. Kamm and A. R. Willey

2. Some Observations on Protection of Steel by Tin, by E. L. Koehler

3. Corrosion Resistance of Electrolytic Tin Plate—Part 2: The Alloy-Tin Couple Test—A New Research Tool, by G. G. Kamm, A. R. Willey, R. E. Beese and J. L. Krickl

4. Accelerated Corrosion Test for Tin Plate in Grapefruit Juice, by P. R. Carter and T. J. Butler

5. Influence on Behavior of Tin-Steel Couple of the Area of the Component by S. C. Britton and K. Bright

Influence of Reactor Radiation on Oxidation of Niobium, by J. V. Cathcart and F. W. Young, Jr.

Corrosion of Materials by Fluorine and Liquid Oxygen, by F. W. Fink and Earl L. White

Threshold Values on Factors Contributing to Stress Corrosion Cracking, by Henry Suss

Effect of Flow Rate on Galvanic Corrosion of Low-Carbon Steels in Sea Water, by Eino Uusitalo

March Issue

Topic of the Month: Increasing Rust Resistance of Tin Plate, by Raymond K. Cohen

Chloride Corrosion and Fouling in Catalytic Reformers and Naphtha Pretreaters, by E. B. Backensto and A. N. Yurick

Hydrogen Pickup During Aqueous Corrosion of Zirconium Alloys, by Warren E. Berry, Dale A. Vaughn and Earl L. White

Corrosion of Reinforcing Steel in Concrete in Marine Atmospheres, by Howard F. Finley

Cathodic Protection and Zinc Grounding in an Industrial Plant, by J. D. Ghesquiere

Massive De-Aluminization of Aluminum Bronze by Chloride Crevice Attack, by L. W. Gleekman and R. K. Swandby

Anodic Polarization of Lead-Platinum Bielectrodes in Chloride Solutions, by L. L. Shreir

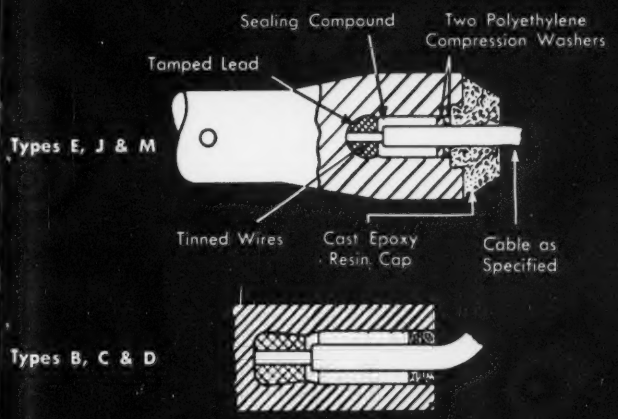
Resistance of Aluminum Alloys to Underground Corrosion, by D. O. Sprowls and M. E. Carlisle, Jr.

Kinetics and Mechanism of Hydrogen Attack, by L. C. Weiner

For more positive cathodic protection of all types of structures used throughout the petroleum industry it's

DURIRON® IMPRESSED CURRENT ANODES

Standardize on DURIRON! In the normal ground bed installations with perfectly (or imperfectly) tamped backfill, DURIRON gives positive protection. But in the tough applications; marshlands, river crossings, or wherever backfilling is impractical, DURIRON outperforms all others. DURIRON can be used without backfill! Buy DURIRON anodes for complete protection with long service life in the toughest services. (And in the easy ones, too.)



STOCK DURCO ANODE SIZES

Type Anode	Size	Area Sq. Ft.	Weight (Lbs.)	General Application
B	1" x 60"	1.4	14	Fresh Water
C*	1½" x 60"	2.0	25	Ground Bed
D	2" x 60"	2.6	46	Ground Bed
E	3" x 60"	4.0	115	Salt Water
G	2" x 9"	0.4	5	Ducts
J	3" x 36"	2.5	80	Salt Water
M	2" x 60"	2.8	57	Salt Water

*Applicable also in fresh water service. Should not be used in ground beds without backfill.

THE DURIRON COMPANY, INC. / DAYTON 1, OHIO

DURCO